TECHNICAL REPORT
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EFFECTS OF DYNEL FIBER BLENDING ON YARN SHRINKAGE AND WOVEN-FABRIC PROPERTIES

by

Paul J. Angelo, Jr., David H. Pfister,
John A. Goodwin and Victor Duxbury

Lowell Technological Institute Research Foundation
Lowell, Massachusetts

Contract No. DA19-129-AMC-894 (N)

January 1967

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

U.S. ARMY MATERIEL COMMAND

Clothing and Organic Materials Division
TS-150

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FOREWORD

The use of nonflammable synthetic fiber in tentage fabric, to meet new weight and bulk limitations, has presented many problems in attaining required waterproofness. Spinning and weaving characteristics have restricted the degree of fabric tightness obtainable on the loom. Also, these fibers do not swell when wetted, as does cotton, to close up remaining channels for water penetration. It has been necessary to develop new technology in design and manufacturing. Because of the unfamiliarity within the industry and low civilian market interest, the burden of development has been borne primarily by the Military.

The project described in the report is a phase of one approach in which a fiber type with high heat-shrinkage potential is incorporated in the yarns. After weaving, the fabric is contracted by heat treatment, to develop tightness. However, the effective closing of apertures has not been consistent in practice, and it appeared that the system is sensitive to the specific modes in yarn shrinkage, bulking and recontouring. It was believed that these behaviors were to a considerable extent controlled by the degree and pattern of interspersion of high-shrink and regular fibers within the yarns. This project is in exploration of the effects of such variables.

The investigation was initiated in January 1966 under Contract No. DA19-129-AMC-894(N). The contract was administered under the direction of the Clothing & Organic Materials Division, U.S. Army Natick Laboratories, with Mr. Richard D. Wells as Project Officer and Mr. Louis I. Weiner as alternate.

The significant contributions in yarn sectioning and photographic techniques made by Professor Fritz F. Kobayashi of the Lowell Technological Institute staff are acknowledged.

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ABSTRACT

Regular and high-shrink Dynel were blended in varying proportions and patterns and spun into 16^s yarns with two twists. Microscopic examination showed semblances of expected groupings, but the high-shrink fibers tended to migrate to the outside. Shrinkages of the yarns in water (200°F) were measured under varying tensions. Minor loading reduced shrinkages to low levels, suggesting that mechanics of shrinkage in free yarn are different than those in fabric. There was little correlation of the yarn shrinkage results with the different combinations. Maximum shrinkage occurred in the 50/50, low-twist, draw-frame yarn with alternate feed. The least shrinkage in blended yarns was in low-twist yarns with greater proportions of high-shrink fiber. A 50/50 picker blend warp was woven with fillings from the various blends and twists. The fabrics were scoured and treated for water repellency. Highest shrinkage in scouring occurred with low-twist fillings while final shrinkage showed the reverse. High-twist filling yarns produced less air permeability. Differences in shrinkage and air permeability among various blend arrangements were not significant. There was little correlation among the results of yarn and fabric shrinkage and air permeability. All water repellency tests were poor; fabrics with low-twist fillings were better than those of high twist. Overall, among blended yarns, the 50/50 pair arrangements with one drawing seemed more favorable and distinctly better than the 50/50 picker blend. (All samples, including some woven with 100 percent regular shrink warp, have been retained by the U.S. Army Natick Laboratories for further analysis.)

EFFECTS OF DYNEL FIBER BLENDING ON YARN SHRINKAGE AND WOVEN-FABRIC PROPERTIES

1. Introduction

The U. S. Army's continuing interest in lightweight tentage is greatly increasing because of new concepts of mobility. With modern systems for air and off-the-road transport, both weight and bulk become critical in deployment and support of operational forces. The limiting requirement has been that of nonflammability, leaving the choice between rather heavy flameproofing treatments for material such as the traditional cotton, or use of inherently nonflammable material. For the latter, the modacrylic fiber "Dynel"* has been the only commercial material proven as meeting the requirement in practical evaluation.

Because of the physical characteristics of fibers of this type it is very difficult to weave a Dynel fabric tight enough for the necessary waterproofness. Also, unlike cotton, Dynel does not swell when wetted, to close up apertures. Another complication is that water-repellent treatments have not proved as generally and consistently effective on the Dynel substrate as on many other fibers.

To overcome these difficulties, one development approach has been to use a portion of heat-shrinkable Dynel so that by heating the fabric after weaving, the yarns will contract in length and thus compact and tighten the fabric. The portion of regular Dynel, not shrinking, is caused to buckle and helps to maintain or increase the yarn bulk and filling power. There have been numerous trials with various distributions and proportions of the two types of Dynel, and with various textures and several methods of heat treatment. Some results have been highly encouraging but there have been many inconsistencies and seeming anomalies. Fabric area contraction and final texture (ends and picks per inch) have proved no reliable measure of resistance to water penetration, and neither has air permeability in the critical range. Apparently the systems being used were sensitive to variables which were not being taken into account, and the modes as well as the amount of shrinkage behavior of fibers and yarns have considerable bearing on the fabric performance.

*Dynel is a registered trademark of Union Carbide Company.

The Army program to control the variables and establish fabric construction and processing technology to achieve uniformly satisfactory results encompasses many phases. The one covered by this contract effort and report is specific as to the effects of fiber distribution within yarns, on the yarn and fabric shrinkage behavior and resulting fabric waterproofness. It was prompted by the question whether "intimate blend" approach, which had been followed by the mills, gave the most favorable distribution of high-shrink and regular fibers for achieving fabric tightness. (Though blended yarn was not the only approach being pursued, from the mill and economy standpoints there are distinct advantages in using the same blend and yarn in both warp and filling. Also, the system with shrinkage in both directions had seemed basically favorable to the result though, as noted, rather sensitive to minor variables.)

The thought was that if the two fiber types were overly interspersed, possibly the high-shrink fibers were restrained by too much contact with the regular fibers, and also that the latter were prevented from buckling and increasing the radial bulk of the yarn. Accordingly, it was decided to explore the effects of varying degrees of radial dispersion and dispersion patterns, as might be done by draw blending of separate slivers. Draw blending also offered potential advantage in achieving uniform linear distribution compared to the randomness of blends prepared by the usual opener and picker systems.

The scope of work was designed to prepare a range of yarns with varying degrees and patterns of dispersion of the two fiber types, and to compare these among themselves and with picker blend yarns with respect to yarn shrinkage potential, shrinkage behavior in the fabric, and resulting waterproofness. It was necessary, for economy, to concentrate on singles yarns and to do most of the fabric weaving on one standard warp which was taken as the 50/50 picker blend on which most mill experience was based. Some samples were also prepared on a second warp of 100 percent regular Dynel for supplemental study and comparison.

The original scope of work provided some options of detail, to be governed by experience at the several stages and by information being obtained in simultaneous studies being made elsewhere.

2. Objective and Requirements

The objective of this project was to determine the most favorable blend balances and blending systems to maximize shrinkage and yarn bulking (filling) power under the restraints of the fabric structure by use of Dynel fibers spun and woven into fabric.

For this purpose, two types of Dynel fiber were used:

a. Regular shrink fibers, "R"-Type 180, 2 denier, 2-inch staple, uncrimped, natural color.

b. High-shrink fibers, "H"-Type 183, 3 denier (approximately 2.4 denier as delivered), 2-inch staple, uncrimped, OG106 (solution dyed).

The contrasting colors were intended to simplify the work of correlating the systems of blending, yarn morphology, and performance values.

Specifically, the work was divided into four processing phases and three laboratory phases.

a. Processing Phase I: Blending at Draw Frame

One hundred pounds each of fiber stocks "R" and "H" were to be processed separately through to card sliver by conventional means for subsequent drawing and spinning to $16^s/1$ (c.c.) yarn. Fifty pounds of each were then to be given one process of pre-blend drawing (8 x 8) to produce the same sliver weight. Draw-frame blending variations were then to be prepared in the following codes and combinations:

Components "R" - Type 180, natural, undrawn

"RD" - Type 180, natural, drawn once

"H" - Type 183, OG, undrawn

"HD" - Type 183, OG, drawn once

Blend Identification	First Drawing Sliver Arrangement	Number of Blending Drawings
4/4 RH Alt D1	RHRHRHRH	1
4/4 RH Alt D2	RHRHRHRH	2
4/4 RH Pr D1	RRHHRRHH	1
4/4 RH Pr D2	RRHHRRHH	2
4/4 RH Core D1	RRHHHHRR	1
4/4 RH Core D2	RRHHHHRR	2
4/4 RDHD Alt D1	RD HD RD HD RD HD RD HD	1
4/4 RDHD Pr D1	RD RD HD HD RD RD HD HD	1
4/4 RDHD Core D1	RD RD HD HD HD HD RD RD	1
4/4 R HD Core D1	R R HD HD HD HD R R	1
5/3 RH Core D1	RRRHHHRR	1
3/5 RH Core D1	RRHHHHHR	1
8 R D1	RRRRRRRR	1
8 H D1	HHHHHHHH	1

All blends were then to be processed through to singles $16^s/1$ (c.c.) yarns, each in two twist levels between 2.8 and 3.7 twist multipliers.

b. Processing Phase II: Blending at Picker

One hundred pounds each of "R" and "H" stock were to be utilized to prepare three picker blends. Fifty pounds of each were to be combined to make 100 pounds of 50/50 RH blend, and proportional quantities of the remainder to make 50 pounds each of 60/40 RH and 40/60 RH blends. Each blend was then to be drawn as necessary for operable spinning and spun to $16^s/1$ (c.c.) yarns at twist levels subsequently to be decided.

c. Processing Phase III: Weaving

Approximately 75 pounds of 50/50 RH (picker blend) yarn of suitable warp twist were to be creeled, wound, dressed, and drawn in as warp for a series of fabric samples with different fillings. The warp was to be drawn in 4 harnesses and reeded with 5 oval reeds at 2 ends per dent to yield 58 sley off the loom. Filling of the same picker blend 50/50 RH was to be used to establish loom settings for operability at 58 picks per inch with maximum cover. Settings were then to remain the same for the remaining filling series. A minimum of 10 yards each was to be woven with the following filling yarns:

50/50 RH (picker blend - Phase II)
60/40 RH (picker blend - Phase II)
40/60 RH (picker blend - Phase II)
4/4 RH Alt D1 (draw blend - Phase I)
4/4 RH Alt D2 (draw blend - Phase I)
4/4 RH Core D1 (draw blend - Phase I)
4/4 RH Core D2 (draw blend - Phase I)
5/3 RH Core D1 (draw blend - Phase I)
3/5 RH Core D1 (draw blend - Phase I)

plus three other filling yarns to be decided.

d. Processing Phase IV: Weaving of Phase I Yarns

The yarns produced in Phase I were to be used as filling across a warp differing from that used in Processing Phase III, the nature of which was to be subsequently decided upon.

e. Laboratory Phase I: Fiber Distribution Patterns

It has been postulated that differences in shrinkage behavior of yarns made from blends of high-shrinkage and regular-shrinkage Dynel fibers can be explained by varying degrees of contact between the two fiber types. It is further considered that lateral clumping of fibers might produce more effective shrinkage than a uniform, intimately dispersed blend. On the other hand, it is thought that to optimize shrinkage, uniform longitudinal dispersion in terms of equal percentages of each fiber type at any given cross section along the length of the yarn is desirable.

To evaluate the nature of the fiber distributions in the experimental yarns produced in Processing Phases I and II, a microscopic technique would be applied to selected yarn specimens with a view to relating subsequent yarn shrinkage behavior to the associated factors of lateral and/or longitudinal fiber distribution.

Selected constructional factors of the yarn, such as twist, number, and possibly evenness, were to be measured as a check on the original constructional requirements, and also to determine if variations from the planned structure could explain differences in observed shrinkage or other relevant factors.

A limited number of stress-strain measurements were to be made to characterize the yarns in terms of mechanical behavior. This could be useful in predicting optimum manufacturing techniques from considerations of the mechanical behavior of the finished fabrics.

Stapling diagrams might also be prepared from the yarns to evaluate differences which might be associated with the particular methods of drawing.

f. Laboratory Phase II: Evaluation of Yarn Properties

Since the major yarn property of interest was shrinkage, the shrinkage potential was to be evaluated in fluid systems as a function of time and temperature, with the yarn in a free and also a restrained configuration. In addition, fiber distribution patterns as outlined in Laboratory Phase I would be repeated on selected yarn specimens after shrinkage.

g. Laboratory Phase III: Evaluation of Fabric Properties

The fabrics attained in Processing Phase III were to be characterized by descriptive analysis, and then portions subjected to a standard finishing procedure, including desizing, scouring, wet development, dry development, and water-repellent application.

The finished samples were then to be tested for construction, weight, air permeability, hydrostatic resistance, and tear and tensile strengths.

3. Processing Phase I: Blending at Draw Frame

Manufacturing Procedures

Table I details the equipment used.

One hundred pounds of regular shrink fibers "R" and one hundred pounds of high-shrink fibers "H" were opened separately by passing them twice through the blending feeder. The opened stock was then fed to the blending reserve and the finisher section of the picker to form breaker laps. Two breaker laps were fed to the blending reserve to form the finisher laps.

An initial trial run was made without using the fancy, but the necessity for its use was clearly evident. The finisher laps were fed to a flat card (see Table I, Carding A) to produce a 52-grain sliver at approximately 9 pounds per hour. Eight card slivers were fed to drawing with a draft of 8 to produce a 52-grain, first-drawn sliver.

Where a second drawing process was required, eight slivers of first drawing were fed with a suitable draft to produce a 52-grain, second-drawn sliver.

One draw-frame sliver for each spindle was fed to roving to produce 1.45 hank (c.c.).

Initially, the roving was double creeled at the spinning frame to produce a $16^s/1$ (c.c.) yarn. A series of yarns were spun from 100 percent "H" fiber with twist multipliers of 2.8, 3.0, 3.4, and 3.7, after which it was decided to standardize upon 2.8 and 3.4 twist multipliers for the various fiber combinations.

It was also decided to discontinue spinning from double-roving and, as a consequence, single-roving was fed with a corresponding reduction in the draft ratio to produce the $16^s/1$ (c.c.) yarn.

The prescribed lots were spun at the two different levels of twist with the exceptions of 4/4 RH Pr D2, 4/4 RDHD Alt D1, 8 R D1, which were spun with 2.8 twist multiplier but not with 3.4 twist multiplier.

Some difficulty was experienced with static electrical charges when the room temperature was lower than 75°F and the relative humidity was less than 50 percent. In the roving frame, the Dayco cots on the front rollers had to be replaced with Accotex cots.

In the winding operation, a MacColl-type slub catcher was required to remove the "torpedo-type" slubs. A Boyce weaver's knotter was used for end piecing.

The organizational data are given in Table II.

TABLE I. PROCESSING PHASE I: BLENDING AT DRAW FRAME

	Equipment Used	
Blending Feeder:	Whitin Model N-4 with Axi-feed attachment.	
Picking	Saco-Lowell single process, type F-4, equipped with blending reserve, Kirschner beater, fringe roll, supersensitive evener motion, pneumatic lap release	
	Beater to feed roll setting	3/8 in.
	Beater Speed	965 rpm
	Fan Speed	1310 rpm
	Pneumatic lap release operated at	25 psi
Carding A	Revolving top flat, H & B, equipped with lickerin wound with #1 rayon wire and continuous-wound fancy roll.	
	Cylinder Speed	165 rpm
	Lickerin Speed	435 rpm
	Doffer Speed	8-1/4 rpm
	Fancy Speed	1250 rpm
	Flats Speed	3 in./min
Carding B	Roller top, Whitin Model M, equipped with 6 workers and strippers, 3-strip fancy, double coiler front, lickerin wound with #1 rayon wire.	
	Cylinder Speed	170 rpm
	Lickerin Speed	435 rpm
	Fancy Speed	1640 rpm
	Doffer Speed	10 rpm
	Strippers Speed	580 rpm
	Worker Settings (back to front)	Thousandths of an inch
	1	26
	2	26
	3	26
	4	24
	5	21
	6	19
	Both coilers used.	

TABLE I. (Cont'd)

Equipment Used

Drawing	Saco-Lowell, 4 delivery, equipped with DS-24 (3 over 4) drafting.	
	Speed	103 feet/min
Roving	Saco-Lowell 10 x 5 x 8 equipped with FS-3 drafting	
	Spindle Speed	810 rpm
Spinning	Whitin Model F-2, 4 in. gauge, 8 in. traverse, 2 in. ring, #2 flanges. Equipped with Whitin superdraft cradles and double apron drafting.	
	Spindle Speed	6100 rpm
Cone Winding	Foster Model 101, equipped with washer-type tensions and precision blade slub catchers	
	Winding speed	485 yd/min

TABLE II. ORGANIZATIONAL DATA

Process	Size Produced	Doublings	Draft
Picker	13 oz/yd	-	-
Card	52 grains/yd	1	110.0
Drawing (First)	52 grains/yd	8	8.0
Drawing (Second)	52 grains/yd	8	8.0
Roving	1.45 hank (c.c.)	1	9.05
Spinning	$16^s/1$ (c.c.)	1	11.6
		(2)*	(23.2)

*Initially produced but subsequently discontinued.

4. Processing Phase II: Blending at Picker

Manufacturing Procedures

Table I details the equipment used.

The fibers in the requisite proportions were opened by passing twice through the blending feeder. The opened stock was then fed to the blending reserve and the finisher section of the picker to form breaker laps. Two breaker laps were fed to the blending reserve to form the finisher laps.

The blended laps were fed singly to the roller card which produced two slivers concurrently. The roller card was used to give additional blending and also as a matter of expediency, since the flat card was fully occupied.

Each blend was drawn twice at the draw-frame process with eight slivers feeding each drawing and with a draft of eight approximately.

One draw-frame sliver for each spindle was fed to roving to produce 1.45 hank (c.c.).

The majority of the material was processed as 50/50 RH picker blend and spun to $16^{s}/1$ (c.c.) with a twist-multiplier of 3.4 to serve as warp-yarn for Processing Phase III - Weaving. Smaller quantities of yarn were produced from the other blends with 2.8 and 3.4 twist multipliers and also a small quantity of 50/50 RH picker blend with 2.8 twist multiplier.

5. Processing Phase III: Weaving

Manufacturing Procedures

Approximately 75 pounds of 50/50 RH (picker blend) yarn, with a twist multiplier of 3.4, were selected for the weaving of the experimental fabrics.

Initially, 40 cones of yarn were creeled and five 40-end jackspools were prepared with sufficient yardage to insure a 200-yard dressed warp, approximately 38 inches wide.

The five jackspools containing a total of 200 ends were mounted on a jackspool stand and 11 200-yard sections were formed on the Dressing reel. The yarn was then wound on a loom beam with an end-and-end lease and the flanges set at 38-inch beam width.

The beam was slash-sized by the Wannalancit Textile Company, Lowell, Massachusetts. Slashing was accomplished on a 5-can slasher using a special size formulation prepared by Colloids, Inc. The slashing formulation, known by Colloids as X-8241A, can be described as a solution of a vinyl acetate copolymer dissolved in methanol and containing a small addition of ammonia. The slashing media were supplied already blended by Colloids and were applied cold (room temperature) without dilution. Colloids expected an approximate solids pickup of about 12 percent. The slasher was operated at about 10 yards per minute at dry-can temperatures in the range of 100° to 130°F.

The aforementioned slashing conditions were selected to avoid any shrinkage of the warp yarn, and thereby maximize shrinking potential of the woven fabrics.

The slashed warp was then drawn in, utilizing a straight draw on 6 harnesses and reeded 2 per dent, approximately 38-inches wide using a No. 29 reed.

After hanging of the warp, a count of the warp ends revealed too great a number per inch (61 ends per inch). The warp was then rereeded using a No. 27-1/2 reed, yielding the desired sley of 58 ends per inch.

The loom was set to yield maximum picks per inch and, once ascertained, weaving of the selected fillings commenced.

Initially, 1/2 yard lengths of each of the 12 selected yarns (high twist multiplier) were woven. These fabrics were to be utilized for subsequent testing phases. Additionally, 10 yards of each selected filling were woven, consisting of 5 yards of each selected filling (high twist) and 5 yards of each (low twist).

Some problems arose with the selvage yarns breaking repeatedly. This was minimized by the addition of two ends of nylon yarn to each edge of the fabric. Furthermore, weaving efficiency was improved by the spraying of the warp yarn in back of the loom with a water-soluble wax material known as "Spray," a product of Specialty Products Company.

A Crompton Knowles S-4 Loom with a Dobby head motion was utilized with a Precision let-off. Double springs were necessary to permit adequate shedding of the harnesses in light of the high warp tension employed.

Table III lists the 12 fillings employed, each section of the fabric being clearly marked for subsequent identification.

TABLE III. FILLINGS UTILIZED

	Filling	Blend
1.	50/50 RH	Picker
2.	60/40 RH	Picker
3.	40/60 RH	Picker
4.	4/4 RH Alt D1	Draw
5.	4/4 RH Alt D2	Draw
6.	4/4 RH Core D1	Draw
7.	4/4 RH Core D2	Draw
8.	5/3 RH Core D1	Draw
9.	3/5 RH Core D1	Draw
10.	4/4 RH Pr D1	Draw
11.	4/4 RDHD Pr D1	Draw
12.	8 R D1	Draw

6. Processing Phase IV: Weaving of Phase I Yarns

A warp was prepared from 100 percent Dynel "R"-Type 180 fiber spun to $16^s/1$ (c.c.) with warp preparation as for manufacturing procedures Phase III - Weaving. Various fillings were used as detailed in Table IV.

The resulting fabrics were desized, scoured, and treated for water-repellency.

TABLE IV. FILLINGS USED FOR PHASE IV WEAVING

Filling	Low Twist (yds)	High Twist (yds)	Regular Twist (yds)
4/4 RH Alt D1		5	
4/4 RH Alt D2		5	
4/4 RH Pr D1		5	
4/4 RH Pr D2		1-1/2	
4/4 RDHD Core D1	5	5	
4/4 RH Core D2		5	
4/4 RDHD Alt D1		5	
4/4 RHD Core D1	5	5	
8 R	5	5	
8 H	5	5	
$18^s/1$ Cotton			5

The above fabric samples were delivered directly to the Natick Laboratories and were not used for evaluation under the contract.

7. Laboratory Phase I: Fiber Distribution Patterns

Laboratory Procedures

Physical tests were performed in accordance with Federal Specification CCC-T-191b.

Yarn Number	1 skein, Method 4021
Yarn Twist	10 tests, Method 4054.1, 2-inch gauge
Break Strength and Elongation	5 tests, Method 4100 using Instron CRE tester; 6 inches per minute cross-head speed; 12 inches per minute chart speed; 10 inches gauge length

The results are tabulated in Table V.

Samples of yarns were wound on a serigraph card with 28 yarns per inch. Photographs of some of these cards were made at magnifications of 1:1 and 4:1.

Two test specimens, about 1-1/2 inches long, of each yarn were embedded in an acrylic resin available commercially from Rohm & Haas Company as Rhoplex M R. These resin-embedded specimens were then embedded in paraffin wax at a temperature not exceeding 140°F.

Cross sections, nominally 20 microns thick, were cut from each end of each test specimen. These were mounted on microscope slides using mineral oil as the mounting medium. No attempt was made to remove the paraffin or resin. The four sections of each yarn were examined microscopically at a magnification of about 100X.

For those yarns in which the four sections showed a reasonably consistent pattern of the two components, a single section was selected as typical and a photomicrograph prepared. For those yarns in which the four sections did not show a reasonably consistent pattern of the two components, photomicrographs were prepared of each cross section. The photomicrographs were made using a magnification of 120X. Fiber distribution in the cross sections was not clearly distinctive in respect to theoretical patterns. However, the following conclusions have been drawn:

a. A comparison of four consecutive cross sections prepared on each of the various yarns revealed a greater consistency on the draw-blend series than on the picker-blend series.

TABLE V. YARN TEST RESULTS

Sample	Yarn No. Cotton Count	Twist Per Inch, "Z"	Break Strength, Grams	Elongation Percent	Count/Strength Product
4/4 RH Alt D1	14.8	11.3	496	14.9	7341
4/4 RH Alt D2	15.5	11.7	506	14.9	7843
4/4 RH Pr D1	14.3	12.5	483	14.1	6907
4/4 RH Pr D2	15.2	11.9	564	15.4	9583
4/4 RH Core D1	15.8	11.0	462	15.0	7300
4/4 RH Core D2	16.5	10.8	465	14.8	7673
4/4 RDHD Alt D1	15.3	11.4	488	14.4	7466
4/4 RDHD Pr D1	15.3	11.3	500	15.5	7650
4/4 RDHD Core D1	16.0	11.3	491	14.6	7856
4/4 RHD Core D1	16.3	11.9	496	15.8	8085
5/3 RH Core D1	16.6	11.4	485	17.0	8051
3/5 RH Core D1	16.9	11.2	504	14.9	8518
8 R D1	14.9	10.6	619	22.2	9223
8 H D1	16.0	11.7	546	13.7	8736

b. None of the cross sections studied revealed a true intimate fiber-to-fiber blend. That is, regardless of blending techniques, the high- and low-shrink fibers appeared to remain in clumps of similar fibers.

c. In many of the cross sections there appears to be a decided tendency of the high-shrink fiber to migrate to the outer regions of the yarn cross section. Yarn 5/3 RH Core D-1 (high twist) is an excellent example of an instance wherein the high-shrink fiber formed a ring about the low-shrink fiber, even though the reverse was the intent of the draw-blend setup.

d. In one instance drawn slivers showed somewhat better cross-sectional patterns than those made up from card sliver directly.

e. Degrees of twist produced no significant change in cross-sectional patterns.

f. Uniformity of shade indicating the degree of fiber mixing was as expected. That is, the picker-blend series was more generally uniform in external appearance, followed by the multiple drawn yarns, and lastly, the single drawn series yarns.

8. Laboratory Phase II: Evaluation of Yarn Properties

a. Test Procedures

It was considered that a differential shrinkage along the length of a yarn might explain some of the water-repellency properties and, therefore, a "short-length" shrinkage test was employed.

For this purpose, twelve yarn specimens, each approximately 15 inches long, were taken from each sample. Each strand of yarn was knotted to form a loop, and the individual loops were pretensioned with an 18-gram load (approximately 0.03 gram per denier) and marked at 11 points spaced at 1-inch intervals.

The loops were immersed in water at 200°F for 10 minutes. Three loops were exposed under each of the tensions: 0, 3.2 grams, 4.3 grams, and 8.5 grams; the appropriate tension being achieved by suspending weights from the loops.

After exposure, the specimens were air-dried at room temperature under zero tension and subsequently measured for shrinkage under an 18-gram load as used for pretensioning. The yarn specimens were measured to the nearest 1/50-inch, thus 10 1-inch shrinkage measurements were made on each specimen to the nearest 2 percent.

Table VI shows the raw data obtained on the various samples with the three loops from each sample designated A, B, and C. Thus the grand mean represents the mean of 30 readings, 10 from each of the loops A, B, and C.

Table VII shows the grand mean of Table VI presented for purposes of easier comparison, and Figures 1 through 10 show the curves for shrinkage plotted against exposure tensions.

b. Comments

The variability as seen from the minimum and maximum values appears fairly consistent for most yarns and, except in one or two instances, is reasonably small.

While differences in shrinkage dependent upon yarn processing history were apparent, the application of 8.5 grams loop load (4.25 grams per single yarn) tended to reduce the shrinkage of most yarns to approximately the same low level. The effect of the application of this light load (considerably less than the pretensioning load of 0.03 grams per denier suggested by ASTM test procedures) was unexpected. The 100 percent Type 183 high shrinkage yarn exhibited only 6 percent shrinkage at low twist and most other yarns shrank only 0 to 4 percent.

TABLE VI. SHRINKAGE PERCENT

Sample		Tension (grams) 0			3.2			4.3			8.5		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
4/4 RH Alt D1	A	14.8	12.0	16.0	6.4	4.0	8.0	7.0	4.0	8.0	2.2	0.0	4.0
Low Twist	B	16.6	16.0	18.0	6.6	4.0	8.0	7.4	6.0	10.0	2.8	2.0	4.0
	C	16.2	14.0	18.0	6.2	4.0	8.0	7.2	6.0	10.0	3.0	2.0	4.0
Grand Mean		15.9			6.4			7.2			2.7		
4/4 RH Alt D2	A	18.4	16.0	22.0	8.8	8.0	12.0	7.2	6.0	10.0	3.2	2.0	4.0
Low Twist	B	17.2	16.0	20.0	9.0	8.0	10.0	8.4	6.0	10.0	3.6	2.0	6.0
	C	16.6	16.0	18.0	7.8	6.0	10.0	7.8	4.0	10.0	3.4	0.0	6.0
Grand Mean		17.4			8.5			7.8			3.4		
4/4 RH Pr D1	A	13.6	12.0	16.0	7.8	6.0	10.0	6.2	4.0	8.0	3.0	2.0	4.0
Low Twist	B	13.8	12.0	16.0	6.8	6.0	8.0	6.6	6.0	8.0	2.8	2.0	4.0
	C	13.4	12.0	16.0	7.8	6.0	10.0	6.4	6.0	8.0	3.2	2.0	4.0
Grand Mean		13.6			7.5			6.4			3.0		
4/4 RH Pr D2	A	14.8	12.0	16.0	7.2	6.0	10.0	5.6	4.0	6.0	3.6	2.0	6.0
Low Twist	B	15.0	14.0	16.0	7.8	4.0	10.0	5.4	4.0	10.0	4.0	2.0	6.0
	C	14.0	12.0	10.0	8.6	8.0	10.0	7.4	4.0	10.0	4.2	2.0	6.0
Grand Mean		14.6			7.8			6.1			3.9		
4/4 RH Core D1	A	13.0	10.0	16.0	7.6	6.0	10.0	5.4	4.0	8.0	3.0	2.0	6.0
Low Twist	B	12.8	10.0	16.0	7.4	4.0	10.0	6.6	4.0	10.0	3.2	2.0	6.0
	C	13.4	12.0	14.0	6.2	6.0	10.0	5.8	4.0	8.0	2.6	2.0	4.0
Grand Mean		13.0			7.7			5.9			2.9		
4/4 RH Core D2	A	8.4	6.0	10.0	4.8	4.0	6.0	2.6	2.0	4.0	1.4	0.0	2.0
Low Twist	B	8.4	6.0	12.0	4.4	4.0	6.0	4.4	4.0	6.0	3.2	2.0	6.0
	C	8.6	8.0	10.0	4.6	4.0	6.0	3.0	2.0	6.0	2.2	0.0	4.0
Grand Mean		8.5			4.6			3.3			2.3		

TABLE VI. (Cont'd)

Sample		Tension (grams) 0 Mean	0 Min	0 Max	3.2 Mean	3.2 Min	3.2 Max	4.3 Mean	4.3 Min	4.3 Max	8.5 Mean	8.5 Min	8.5 Max
4/4 RDHD Alt	A	12.6	12.0	14.0	6.6	6.0	8.0	5.0	4.0	6.0	2.0	0.0	4.0
Dl Low Twist	B	11.8	10.0	14.0	7.0	6.0	8.0	5.2	4.0	6.0	2.2	0.0	4.0
	C	12.6	10.0	16.0	7.2	6.0	8.0	5.2	4.0	6.0	2.2	0.0	4.0
Grand Mean		12.3			6.9			5.1			2.1		
4/4 RDHD Pr Dl	A	10.6	10.0	12.0	6.0	4.0	8.0	5.4	4.0	8.0	2.8	0.0	4.0
Low Twist	B	11.2	8.0	16.0	6.4	6.0	8.0	5.2	4.0	8.0	1.0	0.0	2.0
	C	11.0	10.0	14.0	7.4	6.0	10.0	6.2	4.0	8.0	2.6	0.0	4.0
Grand Mean		10.9			6.6			5.6			2.1		
4/4 RDHD Core	A	8.2	6.0	10.0	4.2	4.0	6.0	3.4	2.0	4.0	1.0	0.0	2.0
Dl Low Twist	B	8.0	6.0	10.0	4.2	2.0	8.0	3.2	2.0	4.0	1.0	0.0	2.0
	C	9.2	6.0	8.0	4.4	4.0	6.0	3.2	2.0	4.0	1.4	0.0	2.0
Grand Mean		8.5			4.3			3.3			1.1		
4/4 RHD Core	A	5.4	4.0	8.0	3.0	2.0	4.0	2.2	0.0	4.0	1.8	0.0	4.0
Dl Low Twist	B	6.2	4.0	8.0	3.2	2.0	6.0	2.4	0.0	4.0	1.2	0.0	2.0
	C	5.2	4.0	8.0	3.4	2.0	6.0	2.0	0.0	4.0	1.0	0.0	2.0
Grand Mean		5.6			3.2			2.2			1.3		
5/3 RH Core	A	5.6	4.0	10.0	1.2	0.0	2.0	2.4	2.0	4.0	0.0	0.0	2.0
Dl Low Twist	B	6.0	4.0	8.0	2.4	0.0	4.0	2.4	2.0	4.0	0.6	0.0	2.0
	C	5.6	4.0	8.0	2.4	0.0	4.0	2.2	2.0	4.0	0.0	0.0	0.0
Grand Mean		5.7			2.0			2.3			0.2		
3/5 RH Core	A	2.4	0.0	4.0	1.8	0.0	4.0	0.4	0.0	2.0	+0.2	+2.0	0.0
Dl Low Twist	B	2.8	2.0	4.0	1.4	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
	C	3.0	2.0	4.0	1.0	0.0	2.0	0.6	0.0	2.0	0.4	+2.0	2.0
Grand Mean		2.7			1.4			0.3			0.1		

TABLE VI. (Cont'd)

Sample		Tension (grams) 0			3.2			4.3			8.5		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
8 R D1	A	7.8	6.0	10.0	5.0	4.0	6.0	2.2	0.0	4.0	0.0	+2.0	2.0
Low Twist	B	7.4	6.0	10.0	5.0	4.0	6.0	3.0	2.0	4.0	+0.4	+2.0	0.0
	C	9.0	8.0	10.0	4.0	2.0	6.0	2.4	0.0	4.0	0.0	0.0	0.0
Grand Mean		8.1			4.6			2.4			+0.1		
8 H D1	A	20.0	20.0	20.0	12.6	10.0	14.0	12.6	10.0	14.0	5.2	2.0	6.0
Low Twist	B	20.0	20.0	20.0	13.4	10.0	16.0	12.6	10.0	16.0	6.8	4.0	8.0
	C	21.2	20.0	22.0	12.0	10.0	14.0	12.0	10.0	14.0	6.2	4.0	8.0
Grand Mean		20.4			12.7			12.4			6.0		
50/50 RH	A	8.6	8.0	10.0	4.6	4.0	6.0	4.8	4.0	6.0	2.0	2.0	2.0
(Picker)	B	8.0	8.0	8.0	4.4	4.0	6.0	4.6	4.0	6.0	1.6	0.0	2.0
Low Twist	C	7.8	6.0	10.0	4.4	4.0	6.0	2.8	2.0	4.0	1.6	0.0	4.0
Grand Mean		8.1			4.5			4.1			1.7		
60/40 RH	A	12.2	10.0	14.0	6.6	6.0	8.0	5.2	4.0	6.0	2.6	2.0	4.0
(Picker)	B	12.8	10.0	14.0	6.8	4.0	10.0	5.2	4.0	6.0	2.2	0.0	4.0
Low Twist	C	11.8	10.0	14.0	7.6	6.0	8.0	5.4	4.0	8.0	3.0	2.0	4.0
Grand Mean		12.3			7.0			5.3			2.6		
40/60 RH	A	1.8	0.0	4.0	+0.4	+2.0	2.0	+0.2	+2.0	2.0	0.2	+2.0	2.0
(Picker)	B	3.0	2.0	4.0	0.0	0.0	0.0	+0.4	+2.0	0.0	+0.6	+2.0	2.0
Low Twist	C	1.6	0.0	2.0	+0.2	+2.0	2.0	+0.2	+2.0	0.0	0.0	0.0	0.0
Grand Mean		2.1			+0.3			+0.3			+0.1		
50/50 RH	A	7.2	6.0	8.0	5.4	4.0	6.0	3.8	2.0	4.0	1.6	0.0	4.0
(Picker)	B	6.2	6.0	8.0	5.4	4.0	8.0	3.8	2.0	6.0	1.2	0.0	2.0
High Twist	C	6.4	4.0	10.0	5.0	4.0	8.0	4.2	4.0	6.0	1.8	0.0	4.0
Grand Mean		6.6			5.3			3.9			1.5		

TABLE VI. (Cont'd)

Sample		Tension (grams) 0			3.2			4.3			8.5		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
60/40 RH	A	14.4	14.0	16.0	6.8	6.0	10.0	4.2	2.0	6.0	2.8	0.0	8.0
(Picker)	B	13.4	12.0	16.0	6.6	6.0	8.0	6.4	4.0	10.0	3.8	2.0	6.0
High Twist	C	14.6	12.0	16.0	6.2	6.0	8.0	5.0	4.0	6.0	3.2	0.0	6.0
Grand Mean		14.1			6.6			5.2			3.3		
40/60 RH	A	13.2	10.0	14.0	8.8	6.0	8.0	7.2	6.0	10.0	2.6	2.0	4.0
(Picker)	B	12.0	10.0	14.0	7.4	6.0	10.0	5.0	4.0	8.0	3.0	2.0	6.0
High Twist	C	12.8	12.0	14.0	8.2	6.0	10.0	6.4	4.0	8.0	4.8	0.0	12.0
Grand Mean		12.7			8.1			6.2			3.5		
4/4 RH Alt D1	A	6.2	4.0	8.0	5.0	2.0	6.0	4.0	2.0	6.0	2.4	2.0	4.0
High Twist	B	6.8	4.0	10.0	5.6	4.0	8.0	5.6	2.0	8.0	2.8	2.0	4.0
	C	8.4	6.0	10.0	5.2	4.0	6.0	4.0	2.0	6.0	1.0	0.0	2.0
Grand Mean		7.1			5.3			4.5			2.1		
4/4 RH Alt D2	A	7.0	2.0	10.0	4.0	2.0	6.0	2.8	0.0	4.0	1.0	0.0	2.0
High Twist	B	8.0	6.0	10.0	4.4	2.0	6.0	2.2	0.0	6.0	1.8	0.0	4.0
	C	8.6	6.0	12.0	4.4	2.0	6.0	3.4	2.0	6.0	1.4	0.0	2.0
Grand Mean		7.8			4.3			2.8			1.4		
4/4 RH Core	A	4.4	2.0	6.0	4.0	2.0	6.0	3.0	2.0	4.0	1.4	0.0	4.0
D1 High Twist	B	6.0	4.0	8.0	3.4	2.0	6.0	2.6	0.0	6.0	2.2	0.0	4.0
	C	5.6	4.0	6.0	2.8	2.0	4.0	2.8	2.0	4.0	0.6	0.0	2.0
Grand Mean		5.3			3.4			2.8			1.4		
4/4 RH Core	A	6.2	4.0	8.0	3.0	2.0	6.0	1.6	0.0	4.0	1.2	0.0	4.0
D2 High Twist	B	6.4	6.0	8.0	4.0	2.0	6.0	2.4	2.0	4.0	2.4	0.0	4.0
	C	6.0	4.0	8.0	3.6	2.0	6.0	2.4	2.0	4.0	1.2	0.0	4.0
Grand Mean		6.2			3.5			2.1			1.6		

TABLE VI. (Cont'd)

Sample		Tension (grams) 0 Mean	0 Min	0 Max	3.2 Mean	3.2 Min	3.2 Max	4.3 Mean	4.3 Min	4.3 Max	8.5 Mean	8.5 Min	8.5 Max
5/3 RH Core	A	5.0	4.0	6.0	2.0	0.0	4.0	1.0	0.0	2.0	0.4	0.0	2.0
Dl High Twist	B	4.0	4.0	4.0	1.6	0.0	4.0	3.2	2.0	4.0	+0.2	+2.0	2.0
	C	6.0	4.0	8.0	2.2	0.0	4.0	1.0	0.0	2.0	1.6	0.0	6.0
Grand Mean		5.0			1.9			1.7			0.6		
3/5 RH Core	A	4.6	4.0	6.0	3.4	2.0	6.0	2.2	0.0	4.0	0.4	+2.0	4.0
Dl High Twist	B	4.4	2.0	6.0	2.6	2.0	4.0	1.8	0.0	4.0	0.2	+2.0	2.0
	C	4.8	4.0	6.0	3.4	2.0	4.0	1.0	0.0	4.0	0.4	0.0	2.0
Grand Mean		4.6			3.1			1.6			0.3		
4/4 RH Pr Dl	A	0.8	0.0	2.0	0.2	0.0	2.0	0.4	0.0	2.0	+0.8	+2.0	0.0
High Twist	B	1.6	0.0	4.0	1.0	0.0	2.0	0.8	0.0	2.0	+1.0	+2.0	0.0
	C	0.8	0.0	2.0	1.0	0.0	2.0	0.2	0.0	2.0	+0.2	+2.0	0.0
Grand Mean		1.1			0.7			0.4			+0.7		
4/4 RDHD Pr	A	11.2	10.0	12.0	6.4	4.0	8.0	5.2	4.0	6.0	2.8	2.0	4.0
Dl High Twist	B	11.2	12.0	14.0	6.6	4.0	8.0	4.8	2.0	6.0	1.8	0.0	4.0
	C	13.0	12.0	14.0	6.8	6.0	8.0	5.0	4.0	6.0	1.4	0.0	4.0
Grand Mean		11.8			6.6			5.0			2.0		

TABLE VI. (Cont'd)

Sample		Tension (grams)											
		0			3.2			4.3			8.5		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
8H D1	A	10.0	10.0	10.0	8.2	8.0	10.0	6.6	4.0	10.0	4.8	4.0	6.0
High Twist	B	11.6	10.0	14.0	8.0	6.0	10.0	6.2	4.0	8.0	3.8	2.0	6.0
	C	11.4	10.0	12.0	8.6	6.0	10.0	7.6	6.0	10.0	4.8	4.0	6.0
Grand Mean		11.0			8.3			6.8			4.5		
4/4 RDHD Core	A	8.6	8.0	10.0	4.4	2.0	6.0	2.4	0.0	6.0	0.0	+2.0	2.0
D1 High Twist	B	8.2	6.0	10.0	3.8	2.0	6.0	3.4	2.0	6.0	3.2	+2.0	4.0
	C	9.0	8.0	10.0	5.2	4.0	8.0	2.0	0.0	4.0	0.0	+2.0	2.0
Grand Mean		8.6			4.5			3.6			1.1		
4/4 RHD Core	A	6.4	4.0	8.0	3.0	0.0	6.0	4.6	2.0	6.0	2.4	0.0	6.0
D1 High Twist	B	5.6	4.0	8.0	3.6	2.0	6.0	3.6	2.0	6.0	1.4	0.0	2.0
	C	7.0	4.0	10.0	3.4	0.0	6.0	2.8	0.0	8.0	0.8	0.0	4.0
Grand Mean		6.3			3.3			3.6			1.5		

NOTE: A "+" indicates a stretch rather than a shrinkage.

TABLE VII. GRAND MEAN SHRINKAGE PERCENT

Sample	Tension (grams) 0		3.2		4.3		8.5	
	Low Twist	High Twist	Low Twist	High Twist	Low Twist	High Twist	Low Twist	High Twist
4/4 RH Alt D1	15.9	7.1	6.4	5.3	7.2	4.5	2.7	2.1
4/4 RH Alt D2	17.4	7.8	8.5	4.3	7.8	2.8	3.4	1.4
4/4 RH Pr D1	13.6	1.1	7.6	0.7	6.4	0.4	3.0	+0.7
4/4 RH Pr D2	14.6	-	7.8	-	6.1	-	3.9	-
4/4 RH Core D1	13.0	5.3	7.7	3.4	5.9	2.8	2.9	1.4
4/4 RH Core D2	8.5	6.2	4.6	3.5	3.3	2.1	2.3	1.6
4/4 RDHD Alt D1	12.3	-	6.9	-	5.1	-	2.1	-
4/4 RDHD Pr D1	10.9	11.8	6.6	6.6	5.6	5.0	2.1	2.0
4/4 RDHD Core D1	8.5	8.6	4.3	4.5	3.3	3.6	1.1	1.1
4/4 RHD Core D1	5.6	6.3	3.2	3.3	2.2	3.6	1.3	1.5
5/3 RH Core D1	5.7	5.0	2.0	1.9	2.3	1.7	0.2	0.6
3/5 RH Core D1	2.7	4.6	1.4	3.1	0.3	1.6	0.1	0.3
8 R D1	8.1	-	4.6	-	2.4	-	+0.1	-
8 H D1	20.4	11.0	12.7	8.3	12.4	6.8	6.0	4.5
50/50 RH (Picker)	8.1	6.6	4.5	5.3	4.1	3.9	1.7	1.5
60/40 RH (Picker)	12.3	14.1	7.0	6.6	5.3	5.2	2.6	3.3
40/60 RH (Picker)	2.1	12.7	+0.3	8.1	+0.3	6.2	+0.1	3.5

NOTE: "+" indicates stretch rather than shrinkage.

Yarn shrinkages under tensions lower than might reasonably be expected during fabric wet processing were less than the anticipated fabric shrinkages. This is presumably attributable to the mechanics of shrinking under the application of a dead-weight load in the case of yarn; whereas in wet processing the fabric is subjected to intermittent and varying load applications. In this context, it is interesting to note that in the initial stages certain measurements of diameter were made before and after shrinkage on zero-tensioned yarns. There was some indication that either no diameter change occurred or there was a possible decrease in diameter even though the yarn shrank. Also, when viewed longitudinally under the microscope, hairiness was less apparent after shrinkage.

It was apparent that yarn shrinkage behavior was different from fabric shrinkage and it was thus pointless in carrying out additional tests such as shrinking the yarn while subjected to restrained configurations. It was therefore decided to transfer the equivalent effort into other phases.

c. Fiber Lengths on Removal from Shrunk Yarn

Measurements of fiber length distributions were made on certain picker blend yarns in accordance with ASTM-D 1440-65 with the exception that the total weight of fiber was less than specified because the fibers were extracted from yarns. Care was taken to insure minimum fiber breakage during untwisting and fiber extractions. The results are recorded in Table VIII.

d. Comments

In the majority of the yarns examined, the longest fibers were mainly "R" type. In general, the long fibers, whether "R" or "H", were either without crimp or exhibited a slightly wavy appearance. The fiber lengths were classified into 14 or 15 intervals and the upper three or four intervals (the longest fiber groups) contained mainly "R" fibers or equal amounts (by estimation) of "R" and "H" fibers. All other intervals contained mainly "H" fibers. The major exceptions to this distribution pattern were the 60/40 RH low-twist yarn and the 40/60 high-twist yarn both shrunk under 8.5 grams tension. In the former, the first eight (8) intervals (longest fibers) and in the latter the first five (5) intervals (longest fibers) contained "R" or equal proportions of "R" and "H" (estimated).

TABLE VIII. FIBER LENGTH (IN.) ANALYSIS ON REMOVAL FROM SHRUNK YARN

Sample	Shrinkage Tension (grams)	Upper Quartile		Mean	
		Low Twist	High Twist	Low Twist	High Twist
Control "R"	(Unshrunk)	---	1.966	---	1.831
Control "H"	(Unshrunk)	---	1.963	---	1.773
60/40 RH Picker	0	1.888	1.926	1.699	1.674
60/40 RH Picker	8.5	1.863	1.917	1.709	1.756
40/60 RH Picker	0	1.916	1.868	1.696	1.591
40/60 RH Picker	8.5	1.898	1.853	1.750	1.540

9. Laboratory Phase III: Evaluation of Fabric Properties

a. Scouring and Finishing Procedures

To minimize hard creases and to provide maximum relaxation and working of the fabric, the 2 selvages of the fabric piece were brought together and tacked to form a tube. The fabric was placed in a Riggs and Lombard Standard Sample Dye-Beck, and wet-out and relaxed for 30 minutes at 120°F. The scouring agent was then added. This consisted of 2 percent by weight of Rohm and Haas Triton X-100. The bath was brought slowly to a boil and the cloth boiled for 1-1/2 hours. It was then rinsed once at 160°F and twice at 80°F. To insure a minimum amount of tension on the fabric, a low reel position was maintained with a slow reel speed of 8 rpm.

The fabric was then untacked and dried in open-width form in an Andrews and Goodrich Continuous Loop Dryer by means of electrical heating. A slight amount of overfeed was employed with a drying temperature of 200°F and a take-off speed of 3 yards per minute.

b. Water-Repellency Treatment Procedure

This process was in accordance with the Natick Laboratories' instructions. The resin was applied by means of a James Hunter Machine Company 3-roll, 15-tons pressure pad with a recorded pressure of 63-1/2 pounds per square inch and a speed of 6 yards per minute.

The padding solution was comprised of:

3.125	gal.	(12.5% by volume)	NALAN GN
0.250	gal.	(1.0% by volume)	ZEPEL 8
21.625	gal.	(86.5% by volume)	WATER

The wet pickup was 46.5 percent with 2.5 percent solids pickup.

After padding, the fabric was held out to 30 inches width on the open-clip tenter. The object of this operation was to remove the creases which were present following the first drying operation, and steam heat was used to dry at the tenter.

The padded and tentered fabric was then cured in the Andrews and Goodrich Loop Dryer with a slight overfeed at a drying temperature of 250°F and a take-off of 2 yards per minute.

c. <u>Test Procedures</u>

Twelve 1/2-yard fabric samples, all woven with "low-twist" filling yarns, were tested for properties as follows:

Ends per inch:	CCC-T-191b, Method 5050.2 (5 determinations)
Picks per inch:	CCC-T-191b, Method 5050.2 (5 determinations)
Air Permeability:	CCC-T-191b, Method 5450.1 (5 determinations)

For purposes of determining changes in these properties and also the degree of shrinkage after scouring, the samples were marked at 3 places in the filling direction with marks at 18-inch intervals, and at 3 places in the warp direction with marks at 10-inch intervals.

The samples were scoured and measured for shrinkage and again for ends and picks per inch and air permeability. The test results are given in Table IX.

Twenty-four 5-yard fabric samples, 12 each woven with "low-twist" and "high-twist" filling yarns were prepared for shrinkage determinations by marking them at 3 places in the warp direction and 3 places in the filling direction, all marks being at 18-inch intervals.

The samples were scoured, measured for shrinkage, and tested for air permeability. Five air permeability measurements were made on each sample in accordance with Method 5450.1 of CCC-T-191b.

The samples were then treated for water repellency, shrinkages were determined, and tests made for air permeability (five measurements for each sample as before). The results of these tests are recorded in Tables X and XI. Additionally, the scoured and water-repellency-treated samples were tested for properties as follows:

Breaking Strength:	CCC-T-191b Method 5100.1 Scott CRT Tester (3 warp and 3 filling determinations)
Tearing Strength:	CCC-T-191b, Method 5132.3 (3 warp and 3 filling determinations)
Fabric Weight:	CCC-T-191b, Method 5041.1
Water Resistance:	Details of "cup-test" procedure supplied by Natick Laboratories (see Appendix)(3 determinations)

The fabrics were conditioned at 70°F and 65 percent RH prior to testing.

TABLE IX. HALF-YARD FABRIC SAMPLES
ENDS AND PICKS, AIR PERMEABILITY, AND SHRINKAGE

Sample	Ends per Inch		Picks per Inch		Air Permeability, CFM		Shrinkage, %	
	Grey	Scoured	Grey	Scoured	Grey	Scoured	Warp Direction	Filling Direction
4/4 RH Alt D1	61	74	47	62	133	2.43	27.5	20.0
4/4 RH Alt D2	61	74	47	62	139	2.61	31.5	19.4
4/4 RH Pr D1	60	76	48	64	153	3.27	33.3	18.7
4/4 RH Core D1	61	74	47	62	149	2.69	25.6	21.3
4/4 RH Core D2	60	75	46	62	136	3.58	25.8	20.3
4/4 RDHD Pr D1	61	76	48	63	144	3.00	25.0	20.6
5/3 RH Core D1	61	72	47	63	131	3.18	41.3	19.3
3/5 RH Core D1	60	75	46	62	132	2.78	27.5	21.3
8 H D1	60	77	47	64	146	2.64	25.0	22.8
50/50 RH (Picker)	61	76	48	62	122	2.54	26.0	20.1
60/40 RH (Picker)	60	75	47	62	131	2.53	26.0	20.8
40/60 RH (Picker)	61	76	47	62	135	2.12	32.3	20.5

TABLE X. FIVE-YARD FABRIC SAMPLES SHRINKAGE PERCENT

Sample	Scoured				Water-Repellency Treated			
	Warp Direction		Filling Direction		Warp Direction		Filling Direction	
	Low Twist	High Twist	Low Twist	High Twist	Low Twist	High Twist	Low Twist	High Twist
4/4 RH Alt D1	22.2	22.5	19.4	19.0	21.8	22.5	20.4	20.8
4/4 RH Alt D2	22.8	22.3	19.9	18.4	23.3	23.1	19.4	22.2
4/4 RH Pr D1	22.6	23.4	19.4	19.7	22.9	23.0	20.5	21.4
4/4 RH Core D1	22.0	21.9	19.9	19.1	22.8	23.3	19.9	21.8
4/4 RH Core D2	24.2	24.4	19.2	19.3	23.8	22.2	19.7	19.9
4/4 RDHD Pr D1	23.3	24.7	20.1	21.1	23.6	23.6	20.8	22.2
5/3 RH Core D1	22.5	21.3	18.9	16.8	21.3	23.3	19.4	22.0
3/5 RH Core D1	24.1	23.6	20.5	19.4	24.1	23.4	20.1	21.5
8 H D1	23.4	23.4	22.5	22.2	23.0	22.6	22.9	24.9
50/50 RH (Picker)	25.2	22.2	19.8	18.5	23.6	23.6	19.2	20.8
60/40 RH (Picker)	25.1	22.1	19.8	18.1	22.6	23.4	18.4	22.2
40/60 RH (Picker)	23.5	22.1	19.8	18.9	22.9	23.4	20.0	21.8

TABLE XI. AIR PERMEABILITY (CFM) OF FIVE-YARD SAMPLES

Sample	Scoured		Water-Repellency Treated	
	Low Twist	High Twist	Low Twist	High Twist
4/4 RH Alt D1	4.05	2.89	3.26	2.46
4/4 RH Alt D2	3.95	3.92	3.15	2.89
4/4 RH Pr D1	2.52	2.40	3.69	2.61
4/4 RH Core D1	3.10	3.45	2.84	2.87
4/4 RH Core D2	3.48	2.79	3.33	3.05
4/4 RDHD Pr D1	2.85	2.59	3.40	3.20
5/3 RH Core D1	3.81	3.09	4.67	3.45
3/5 RH Core D1	2.92	2.30	3.85	2.56
8 H D1	2.62	2.05	3.10	2.78
50/50 RH (Picker)	2.75	3.34	2.87	1.88
60/40 RH (Picker)	3.06	3.98	3.06	2.63
40/60 RH (Picker)	3.89	2.98	2.85	2.35

TABLE XII. BREAKING STRENGTH (lb) OF FIVE-YARD SAMPLES (WATER-REPELLENCY TREATED)

Sample	Warp Direction		Filling Direction	
	Low Twist	High Twist	Low Twist	High Twist
4/4 RH Alt D1	129	126	138	129
4/4 RH Alt D2	134	147	133	137
4/4 RH Pr D1	134	142	126	134
4/4 RH Core D1	138	130	131	131
4/4 RH Core D2	141	112	125	133
4/4 RDHD Pr D1	139	139	126	128
5/3 RH Core D1	135	130	124	119
3/5 RH Core D1	134	128	131	134
8 H D1	156	147	167	160
50/50 RH (Picker)	137	126	136	130
60/40 RH (Picker)	127	135	128	128
40/60 RH (Picker)	137	128	140	141

The results of the breaking strength, fabric weight, and water-resistance tests are recorded in Tables XII, XIV, and XV, respectively. For the tearing-strength test, trial runs indicated that the tearing strength of the fabrics was about equal to or greater than 85 percent of the capacity of the instrument (with single augmenting weight). The test specimens were, therefore, forwarded for testing at Natick Laboratories and the results are recorded in Table XIII.

d. Comments

The warp-direction shrinkages of some of the 1/2-yard samples were high, and these results were not corroborated when the 5-yard samples were tested. It is considered that the sample size influenced the short-length sample behavior. The filling direction shrinkages of the 1/2-yard and 5-yard samples are in close agreement.

Creases in the pieces probably influenced both the shrinkage and air permeability results; this condition was more marked in the 1/2-yard samples than in the 5-yard samples.

The majority of the breaking-strength results obtained were jawbreaks. Extensive trials with padding of jaws, use of rosin, and change of clamping pressures did not overcome this condition. A few "good" breaks were observed and the results were of the same order of magnitude as the jawbreaks.

As a check on water resistance, two samples of 8H D1 high twist, one of which had previously been tested and had failed and a further untested, but water-repellency-treated sample were recured at 340°F for eight minutes. There was a slight stiffening of the "hand" of the fabrics but they were still considered to be reasonably good. The two samples were subjected to the Natick "cup-test" for water-resistance evaluation. The sample which had previously been tested and failed in about 25 minutes, after reprocessing, failed in 22 hours. The previously untested sample allowed one drop of water to pass in 22 hours but no further percolation took place in 24 hours. This was considered to have passed the test.

In an attempt to isolate the effect of water-repellency treatment, two additional samples were prepared for testing. One sample had been desized and scoured only and the other desized, scoured, and water-repellency treated. Both samples were exposed to a curing temperature of 340°F for eight minutes. The "hand" was found to be very stiff, and in subjecting them to the "cup-test" difficulty was experienced in depressing them into a beaker. This resulted in crease formation rather than a smooth contour of the test fabric. However, the test was performed and the non-water-repellent-treated sample failed immediately while the treated sample failed in about four hours.

TABLE XIII. TEARING STRENGTH (LB) OF FIVE-YARD SAMPLES (WATER-REPELLENCY TREATED)

Sample	Warp Direction		Filling Direction	
	Low Twist	High Twist	Low Twist	High Twist
4/4 RH Alt D1	6.41	6.47	5.44	5.03
4/4 RH Alt D2	6.52	6.56	5.86	5.00
4/4 RH Pr D1	6.21	6.41	5.02	5.16
4/4 RH Core D1	6.19	6.21	5.35	5.20
4/4 RH Core D2	6.65	6.74	5.31	5.49
4/4 RDHD Pr D1	6.01	7.20	5.31	5.47
5/3 RH Core D1	6.30	7.24	5.53	5.55
3/5 RH Core D1	6.14	6.45	5.93	5.18
8 H D1	6.34	6.06	7.28	7.20
50/50 RH (Picker)	5.62	5.82	5.33	5.27
60/40 RH (Picker)	6.04	6.80	4.96	5.25
40/60 RH (Picker)	5.75	7.09	5.95	6.28

TABLE XIV. FABRIC WEIGHT (OZ/SQ YD) OF FIVE-YARD SAMPLES (WATER-REPELLENCY TREATED)

Sample	Low Twist	High Twist
4/4 RH Alt D1	8.4	8.8
4/4 RH Alt D2	8.4	8.7
4/4 RH Pr D1	8.4	9.0
4/4 RH Core D1	8.5	8.6
4/4 RH Core D2	8.4	8.7
4/4 RDHD Pr D1	8.4	8.6
5/3 RH Core D1	8.3	8.4
3/5 RH Core D1	8.5	8.4
8 H D1	8.7	9.0
50/50 RH (Picker)	8.3	8.7
60/40 RH (Picker)	8.4	8.6
40/60 RH (Picker)	8.6	8.9

TABLE XV. WATER RESISTANCE OF FIVE-YARD SAMPLES (WATER-REPELLENCY TREATED)

Sample	Failure Time (minutes)	
	Low Twist	High Twist
4/4 RH Alt D1	7	7
4/4 RH Alt D2	8	7
4/4 RH Pr D1	30	10 (One specimen took one hour to fail)
4/4 RH Core D1	15	7
4/4 RH Core D2	15	7
4/4 RDHD Pr D1	30	25
5/3 RH Core D1	30	7
3/5 RH Core D1	30	7
8 H D1	25	25
50/50 RH (Picker)	10	7
60/40 RH (Picker)	10	7
40/60 RH (Picker)	10	7

10. Observations

Yarn Shrinkage Behavior

The recorded values of yarn shrinkages are not necessarily absolute values. Due to the method of marking the individual yarns at one-inch intervals to determine shrinkage over short intervals, it is possible that both fiber and twist readjustment were inhibited to some extent. However, the results are relative and comparable, subject to the foregoing qualification.

Figure 1 shows the curves of yarn shrinkage plotted against applied load for yarn spun from 100 percent high-shrink fiber (8 H D1) with low and high twist (2.8 and 3.4 twist multipliers) and 100 percent regular fiber (8 R D1) with low twist (2.8 twist multiplier). Low-twist yarn spun from high-shrink fiber shows the greatest shrinkage values at zero and all other loads.

Figure 2 again demonstrates that maximum shrinkage occurs with low-twist yarn with draw-frame blended slivers (50 percent high shrink and 50 percent regular shrink) arranged alternately at the feed (RH Alt). Two blending drawings appear to be slightly better than one in terms of higher yarn shrinkage values, and the 50/50 blend has shrinkage values approximately midway between the 100 percent regular-shrink and 100 percent high-shrink fibers. With high-twist yarn there appears to be slightly more shrinkage with one blending drawing (RH Alt D1) when load is applied. Figures 2A, 2B, 2C and 2D illustrate the corresponding yarn cross sections.

Figure 3 illustrates the effect of arranging the slivers in pairs (RH Pr D1; RH Pr D2). Again, low twist is more favorable to greater yarn shrinkage with little difference between one or two blending drawings. Shrinkage values are somewhat lower than the alternate sliver arrangement, but high twist RH Pr D1 is appreciably lower. Figures 3A, 3B, and 3C show the corresponding yarn cross sections. It will be noted that Figure 3C reveals an accumulation of dark fibers (high shrink H type), whereas Figures 2A, 2B, 2C, 2D, and Figures 3A and 3B show a reasonably homogeneous fiber arrangement. On this evidence it would appear that lateral clumping of fibers is not conducive to high yarn shrinkage. However, inspection of Figure 3C suggests that the percentage of "H" type fibers is somewhat lower than the nominal fifty, and this is confirmed by longitudinal inspection of the yarn (the appearance of which is lighter in shade than the other yarns of similar nominal construction).

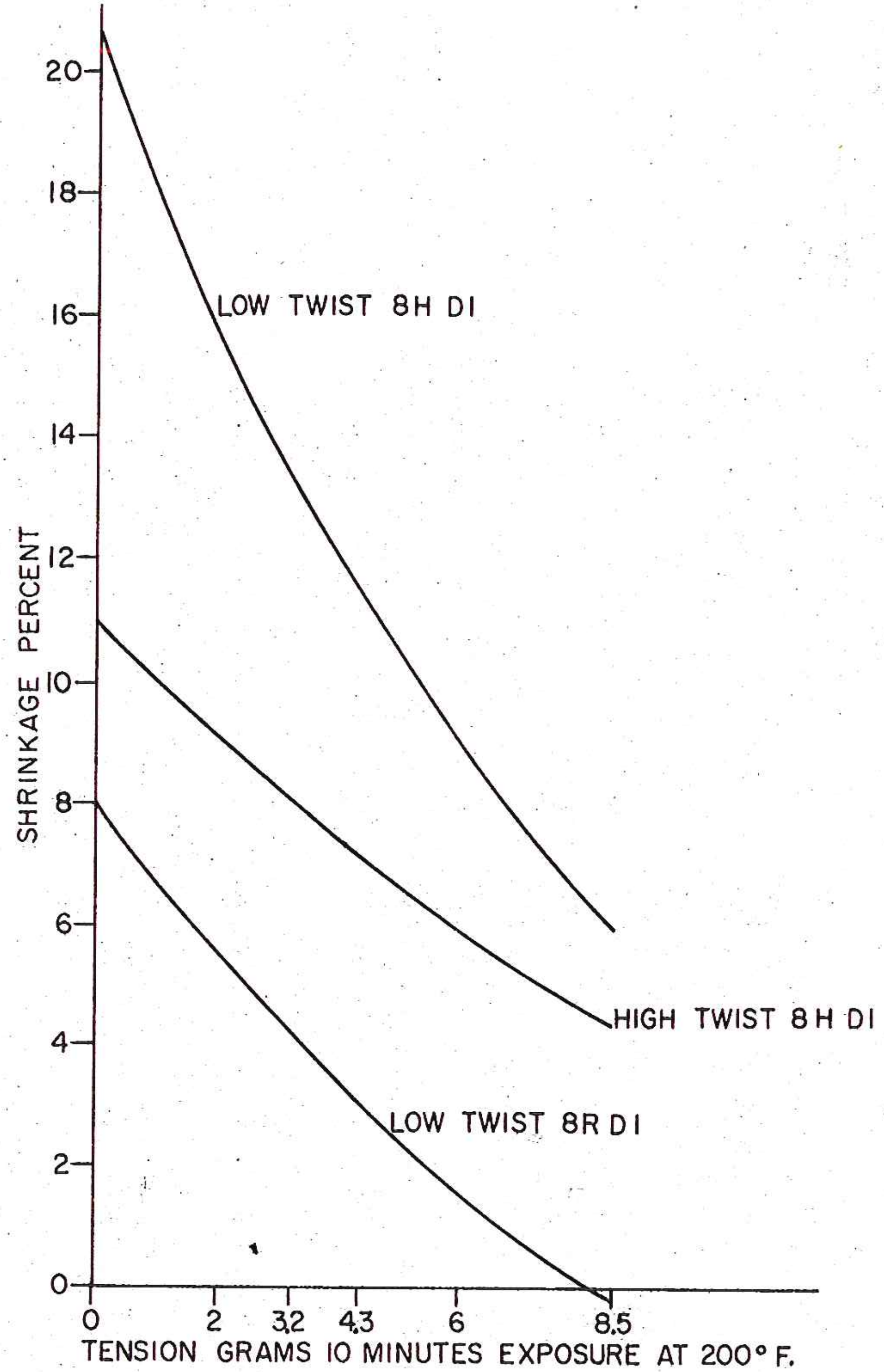
Figure 4 shows the effect of arranging draw-frame slivers with the "H"-type fibers as a core. Again, the low-twist yarns have higher shrinkage values than the high-twist yarns; but in this instance the single blending-drawing is superior to the two passage blending-drawing. The corresponding cross sections

(Figures 4A and 4B) do not reveal any significant differences in fiber arrangement; however, inspection of the yarn longitudinally reveals that 4/4 RH Core D2 is less mottled (that is, has a more uniform appearance than 4/4 RH Core D1).

Figures 5 and 6 show, respectively, the effects on shrinkage of core arrangements of "H" fibers in different proportions with low and high twists. The shrinkage superiority of low-twist 4/4 RH Core D1 is clearly demonstrated. However, low-twist 5/3 RH Core D1 is not significantly different from high-twist 5/3 RH Core D1. Somewhat surprisingly, 3/5 RH Core D1 at both low and high twists exhibits a low level of shrinkage in spite of the presence of a higher percentage of "H"-type fibers. This is again seen to occur in Figure 9 with low-twist 40/60 RH picker blend. Inspection of Figure 5B fails to provide a clue to this behavior, but longitudinal comparison of the two yarns reveals that there is greater uniformity of fiber blending (3/5 RH Core D1).

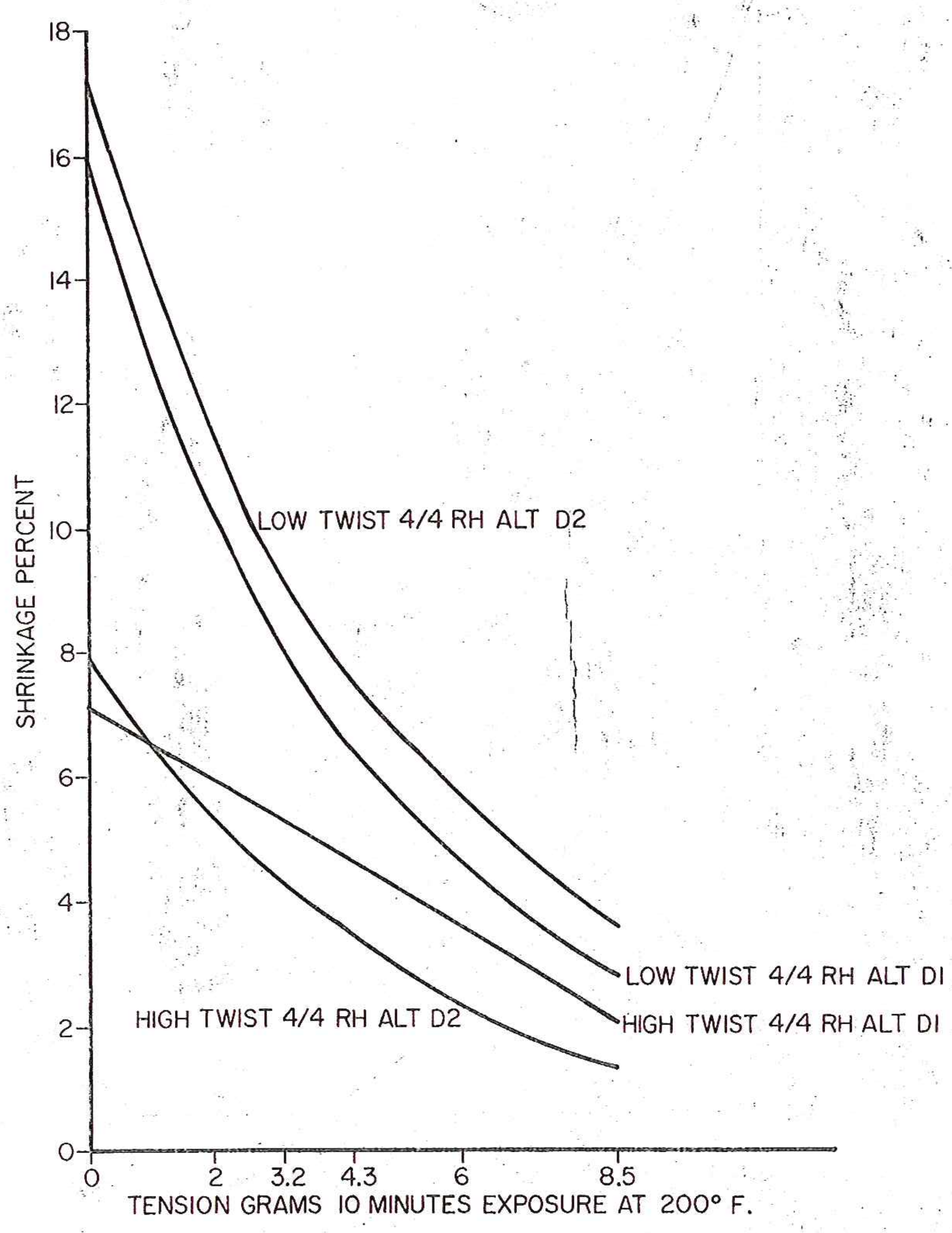
The effect of drawing prior to blending is demonstrated in Figures 7 and 8. There appears to be little difference between low and high-twist effects, but the RHD Core D1 combination gives lower shrinkage values than the corresponding RDHD Core D1 at both low and high twists. Examination of the corresponding cross sections indicates a somewhat superior comingling of the two fiber types in Figures 7A when compared with 7B, 7C, and 7D, and Figure 8A, similarly, is slightly better than 8B and 8C.

The picker blends of Figure 9 low twist and Figure 10 high twist demonstrate the higher shrinkage values obtained with high-twist yarns for the various percentages of fiber combinations. This is, of course, a reversal of the behavior with draw-frame blending. Inspection of the corresponding yarn cross sections in Figures 9A, 9B, and 9C, indicates reasonably intimate blending in all instances. The shrinkage superiority of the 60/40 RH blend over the 50/50 blend is clearly demonstrated at both twist levels. The interesting behavior of the 40/60 RH blend, particularly at low twist, confirms the findings with draw-frame blends of similar fiber percentages.



SHRINKAGE IN WATER OF 100% "H" AND "R" TYPE YARNS 16/1cc

FIGURE 1



SHRINKAGE IN WATER OF 4/4 RH ALT YARNS 16/1 cc

FIGURE 2

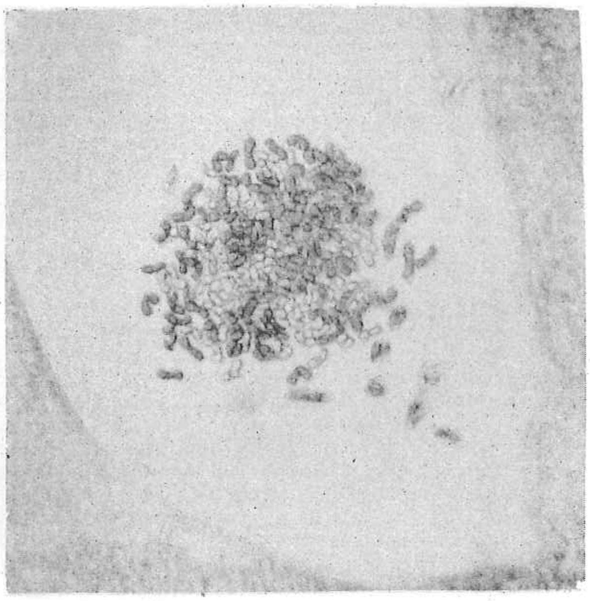


Figure 2A

Low-Twist 4/4 RH Alt D2

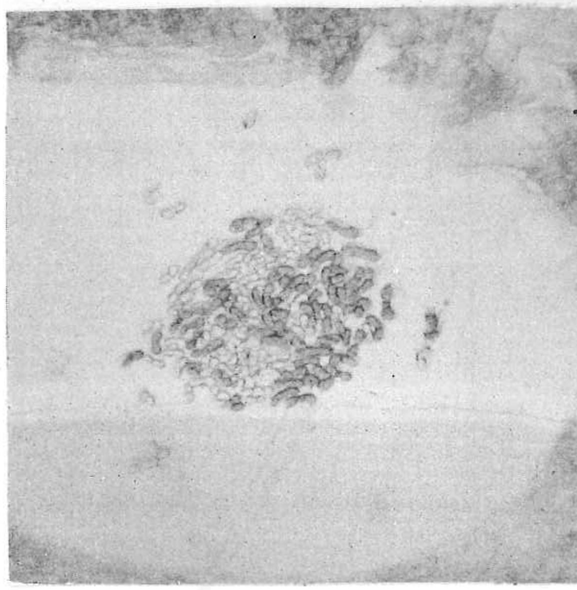


Figure 2B

Low-Twist 4/4 RH Alt D1

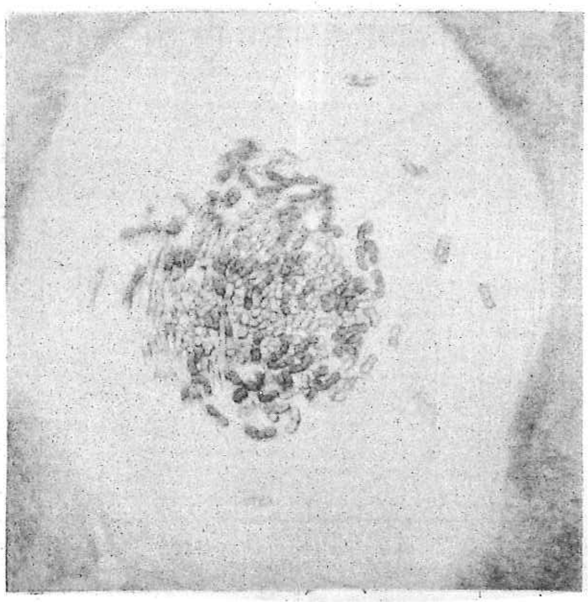


Figure 2C

High-Twist 4/4 RH Alt D2

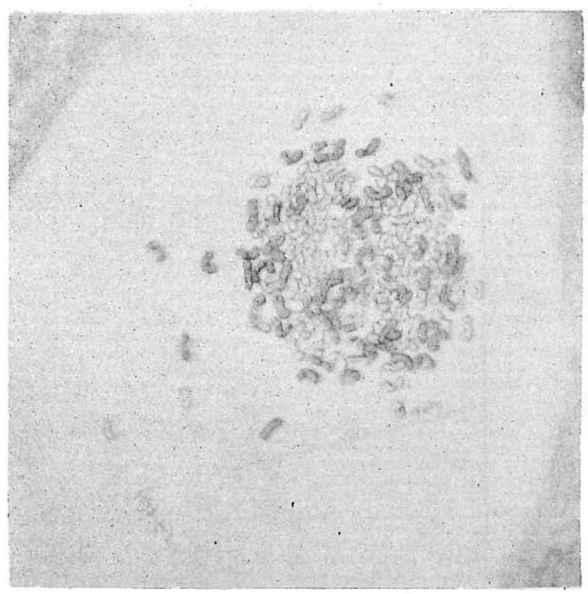
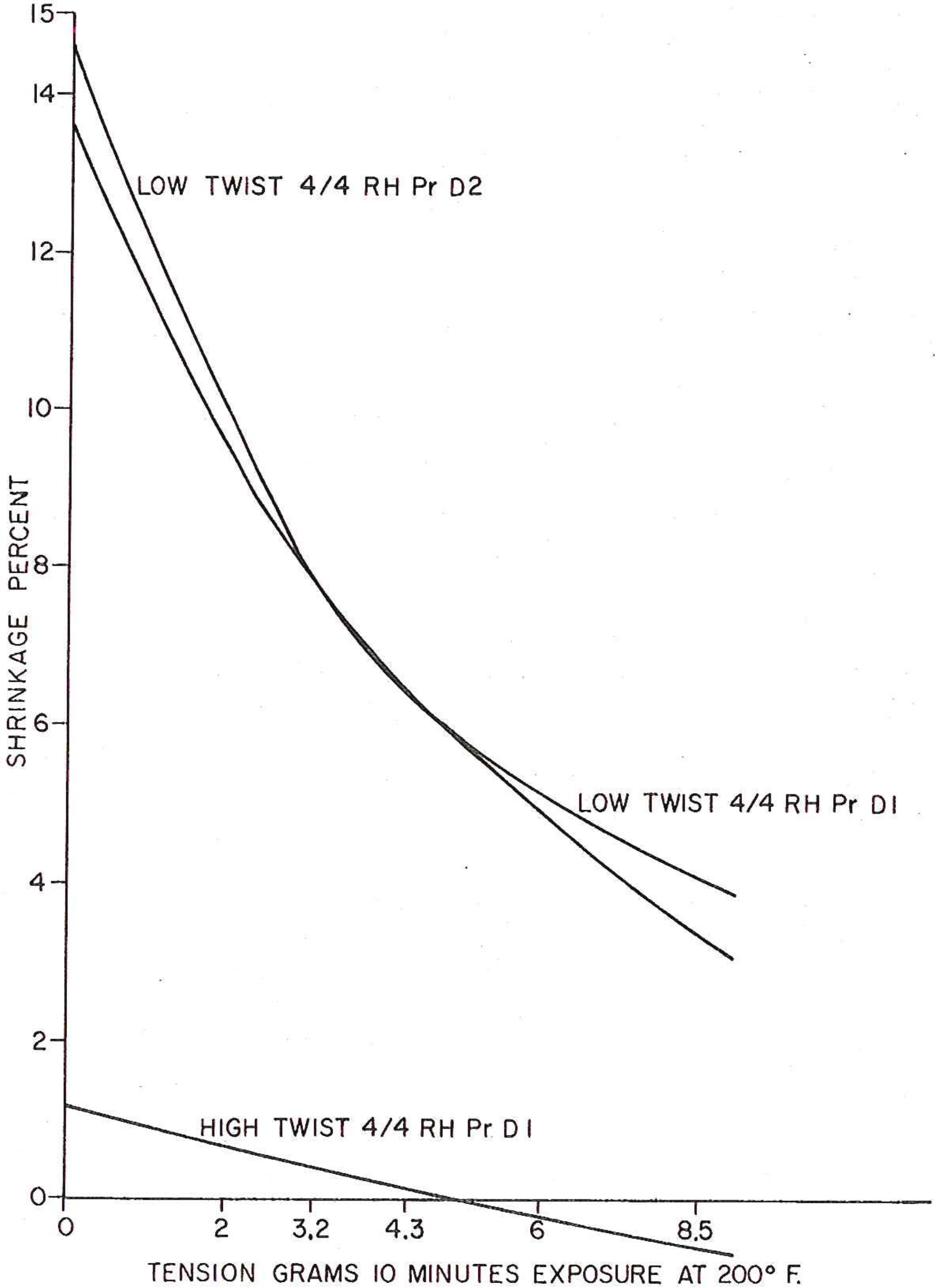


Figure 2D

High-Twist 4/4 RH Alt D1



SHRINKAGE IN WATER OF 4/4 RH Pr YARNS 16/1cc

FIGURE 3

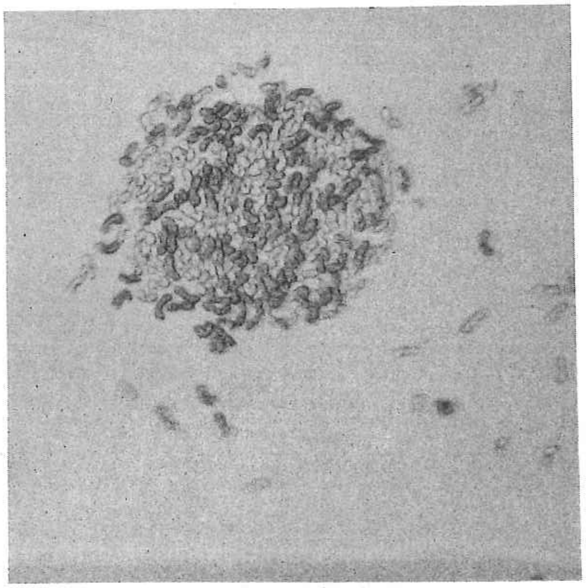


Figure 3A

Low-Twist 4/4 RH Pr D2

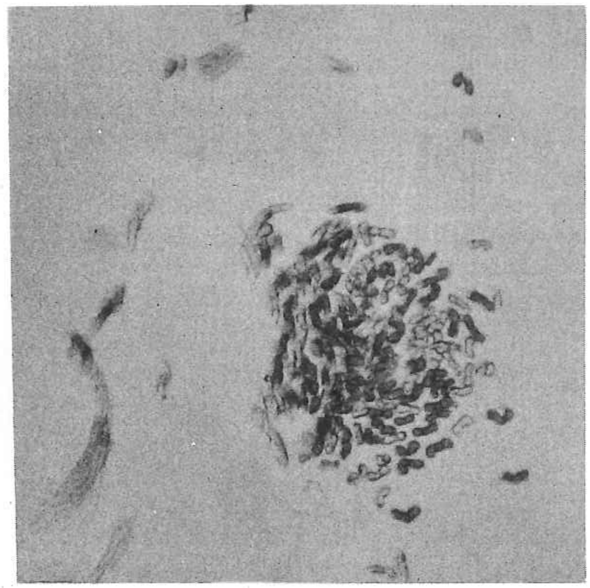


Figure 3B

Low-Twist 4/4 RH Pr D1

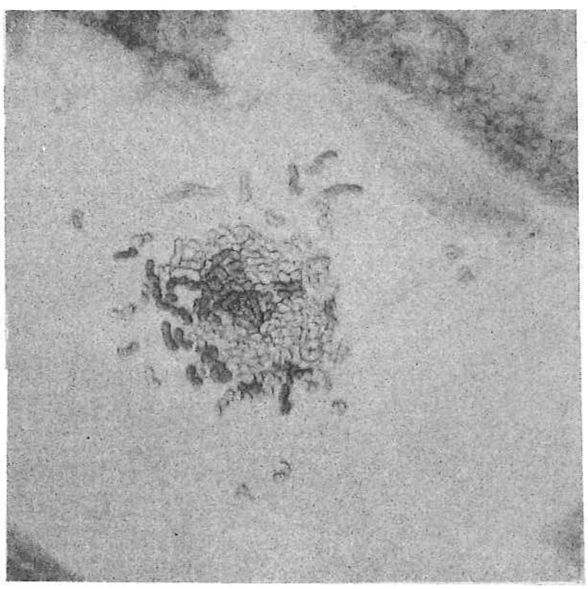
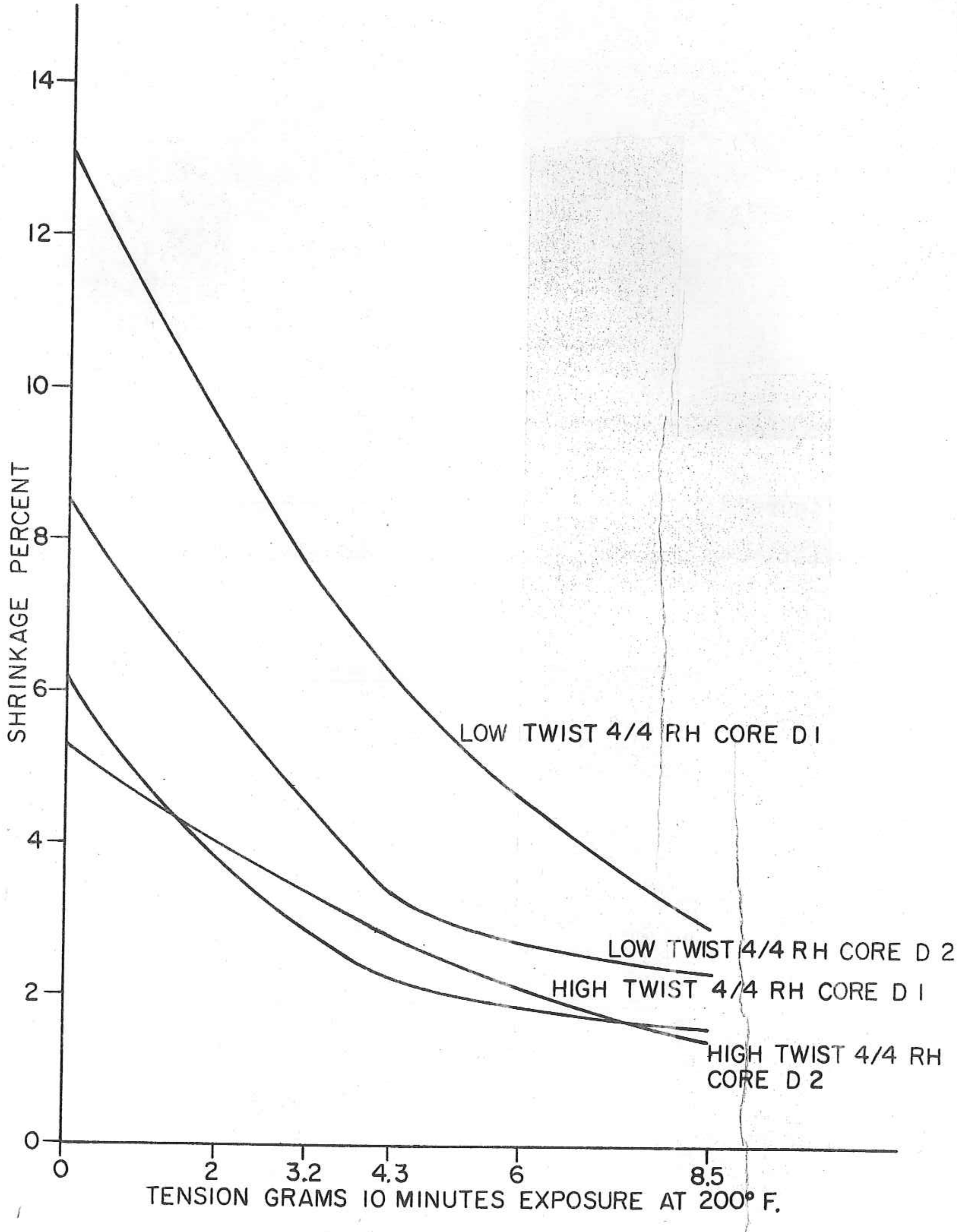


Figure 3C

High-Twist 4/4 RH Pr D1



SHRINKAGE IN WATER OF 4/4 RH CORE YARNS 16/1 cc

FIGURE 4

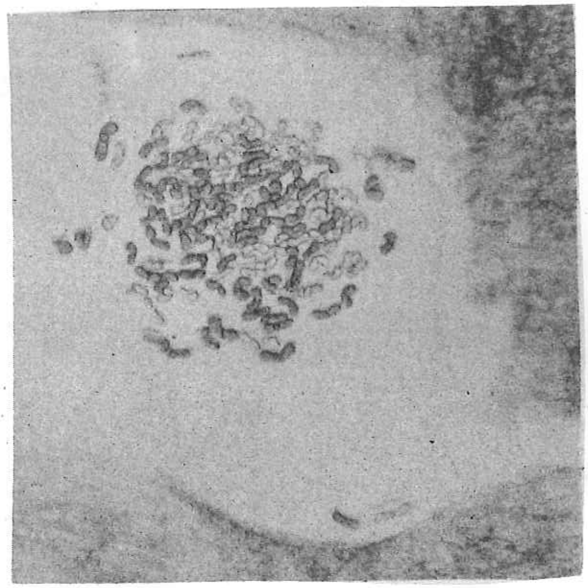


Figure 4A

Low-Twist 4/4 RH Core D1

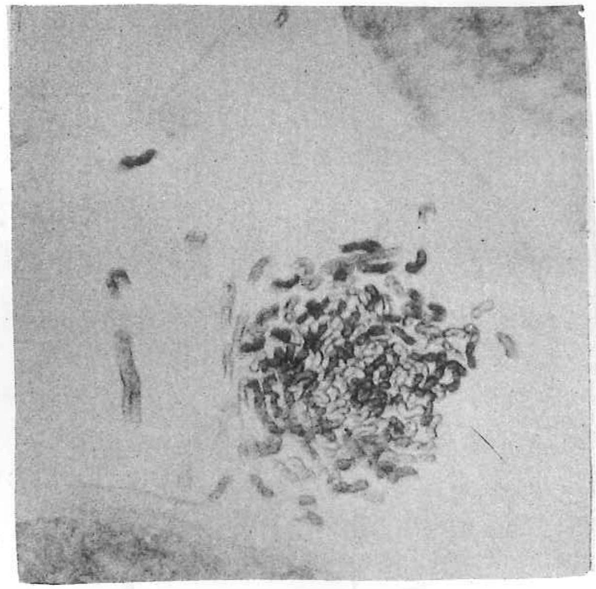


Figure 4B

Low-Twist 4/4 RH Core D2

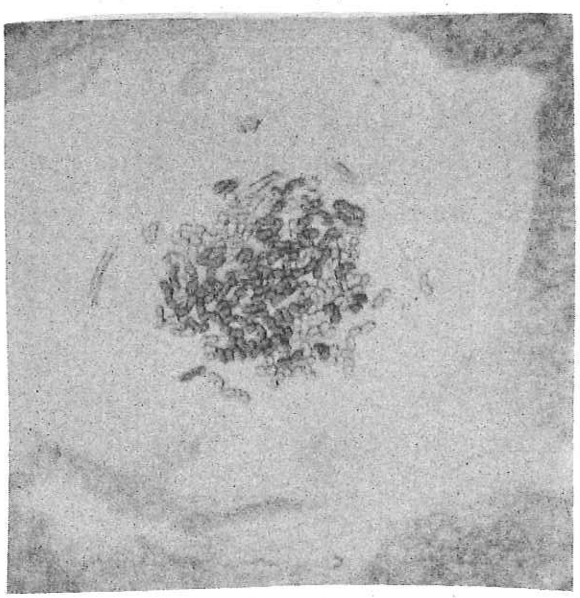


Figure 4C

High-Twist 4/4 RH Core D1

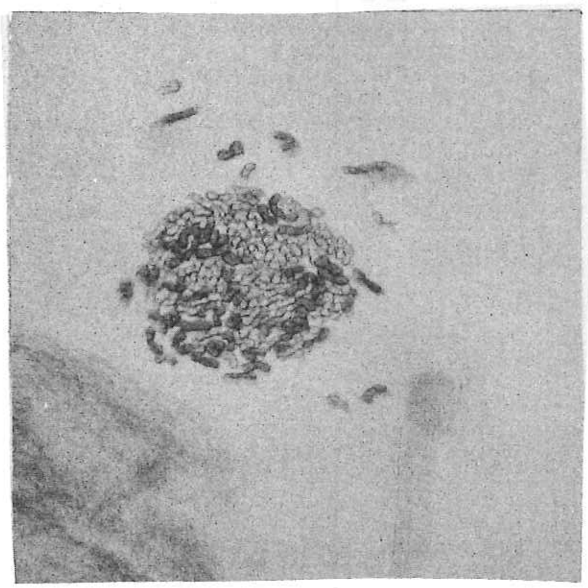
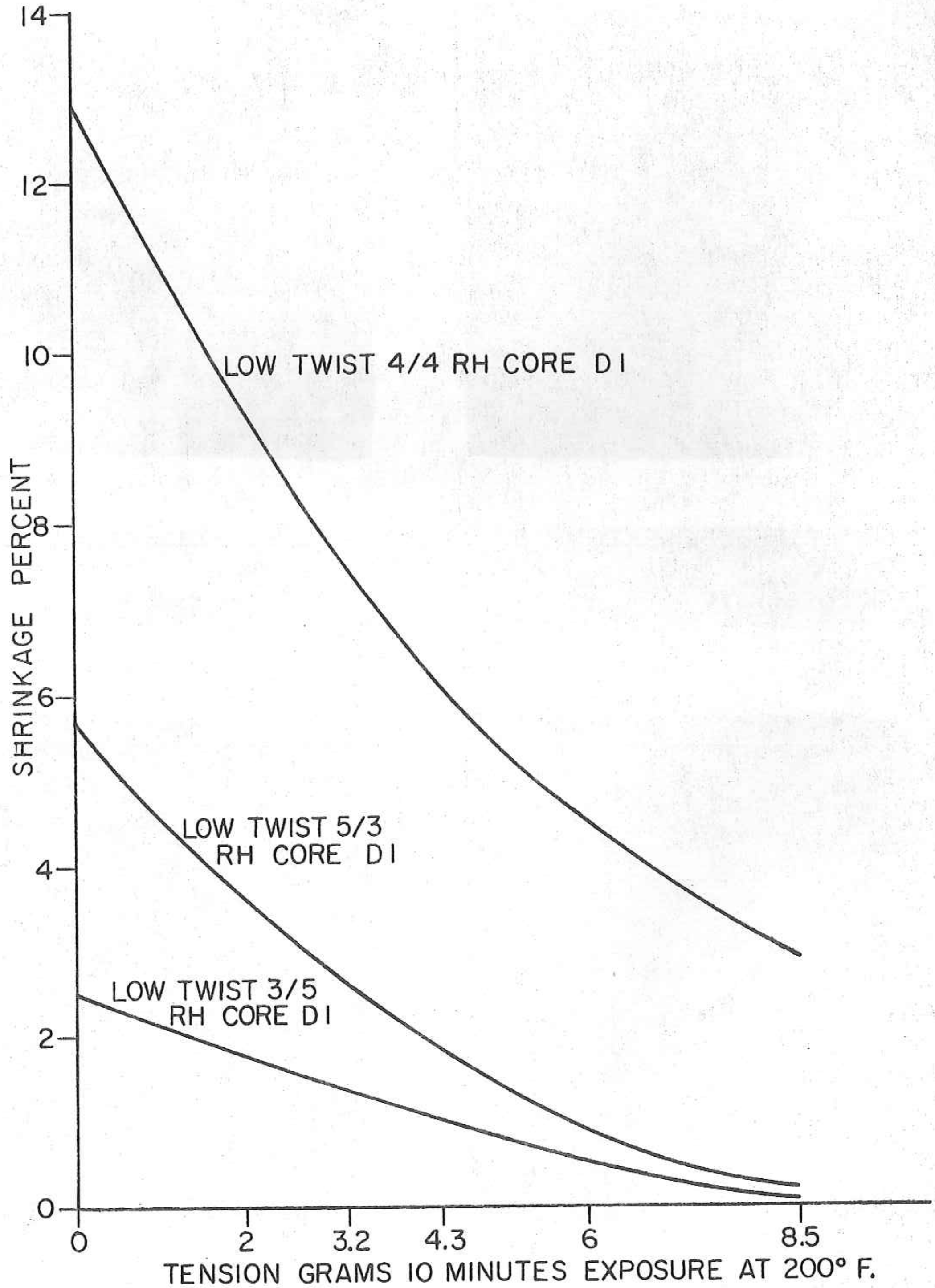


Figure 4D

High-Twist 4/4 RH Core D2



SHRINKAGE IN WATER OF 4/4 RH, 5/3 RH AND 3/5 RH CORE LOW TWIST YARNS 16/1 cc

FIGURE 5

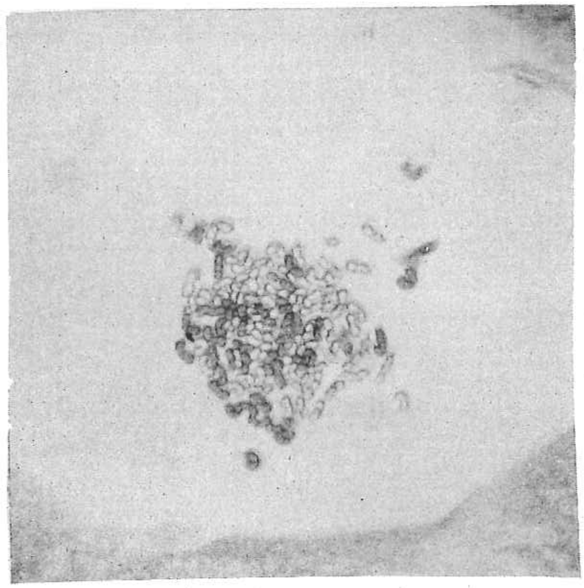


Figure 5A

Low-Twist 5/3 RH Core D1

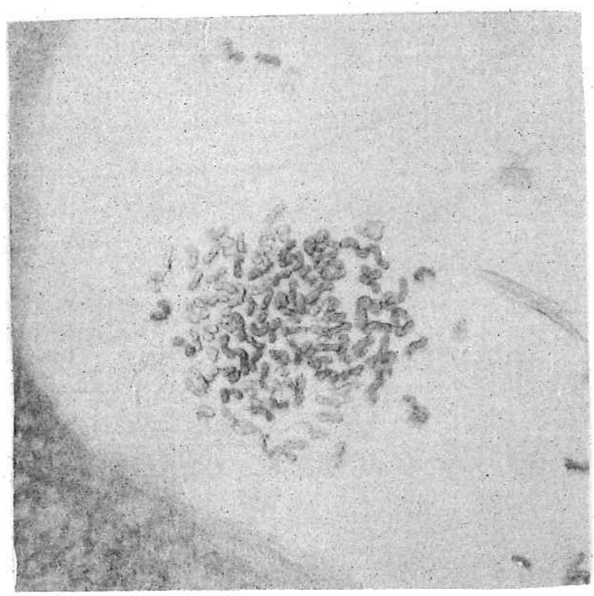
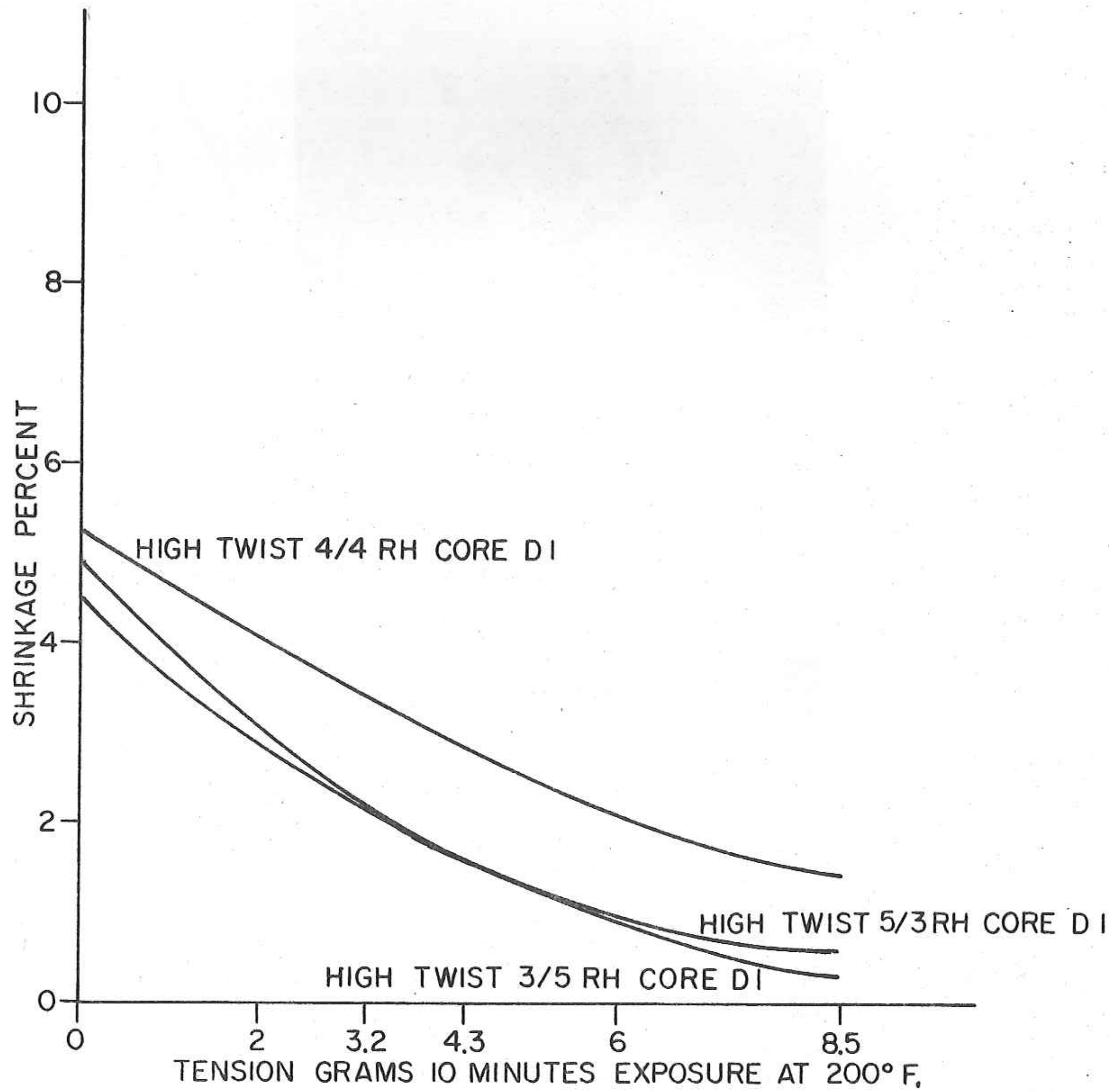


Figure 5B

Low-Twist 3/5 RH Core D1



SHRINKAGE IN WATER OF 4/4 RH, 5/3 RH AND 3/5 RH CORE HIGH TWIST YARNS 16/1cc

FIGURE 6

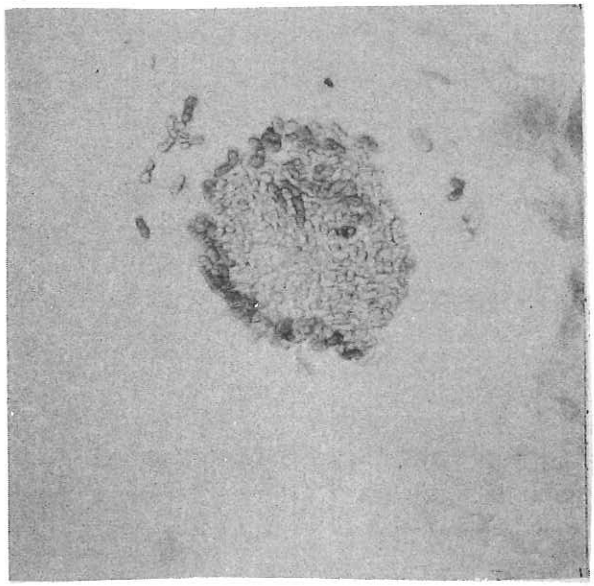


Figure 6A

High-Twist 5/3 RH Core D1

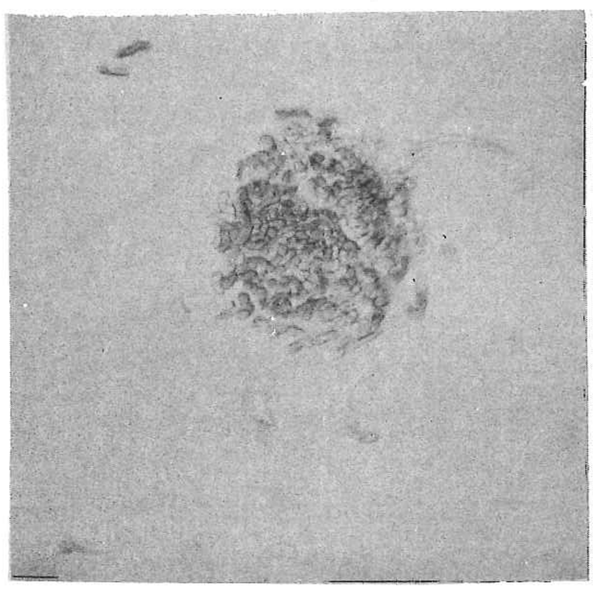
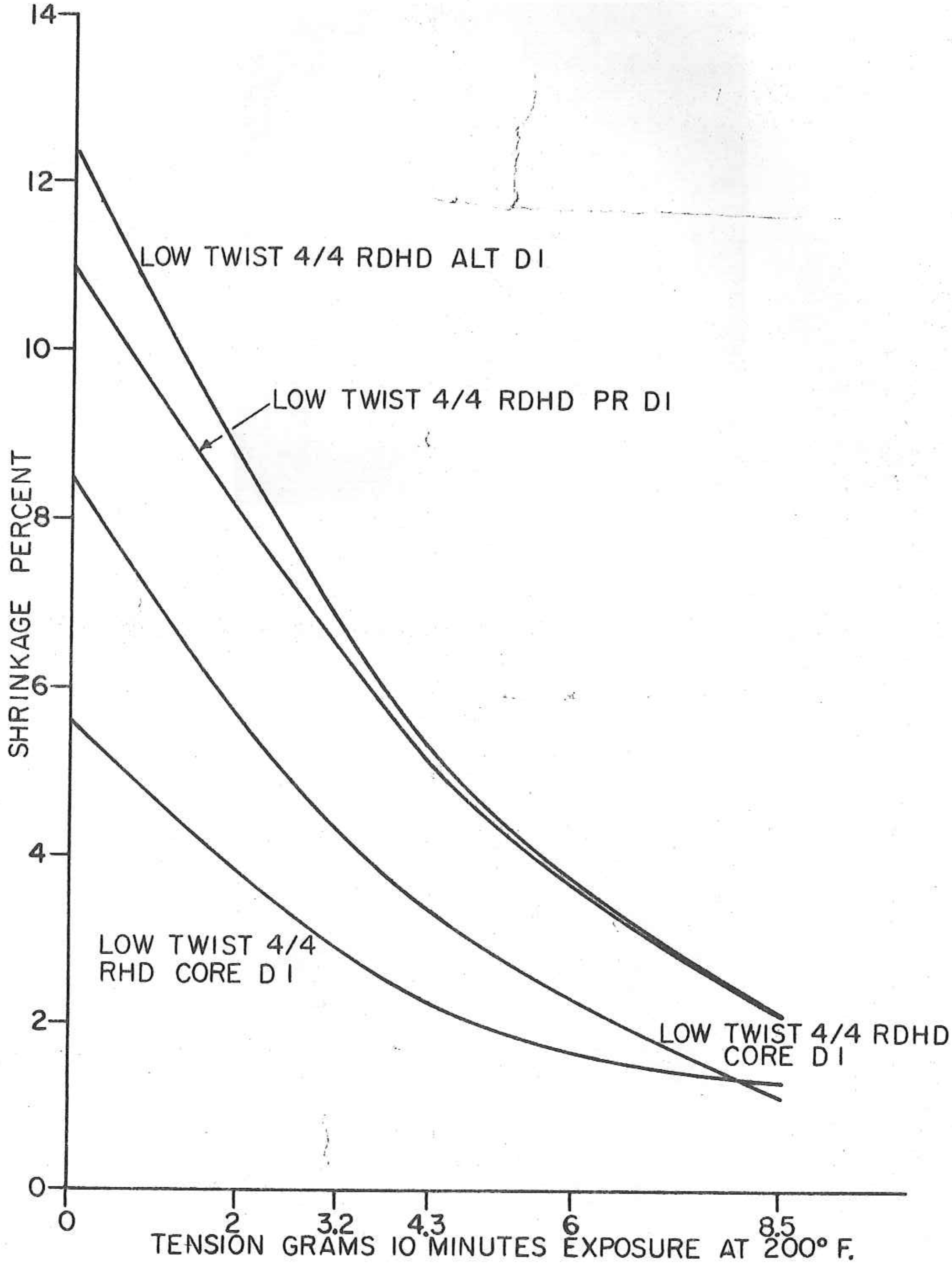


Figure 6B

High-Twist 3/5 RH Core D1



SHRINKAGE IN WATER OF 4/4 RDHD AND

4/4 RHD LOW TWIST YARNS 16/1 cc

FIGURE 7

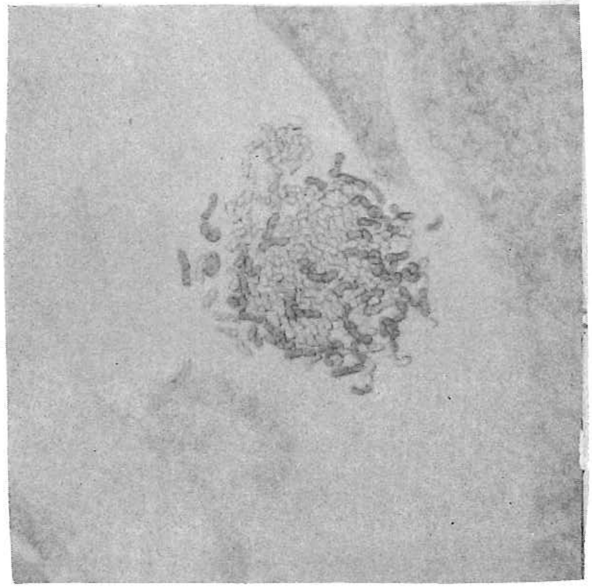


Figure 7A

Low-Twist 4/4 RDHD Alt D1

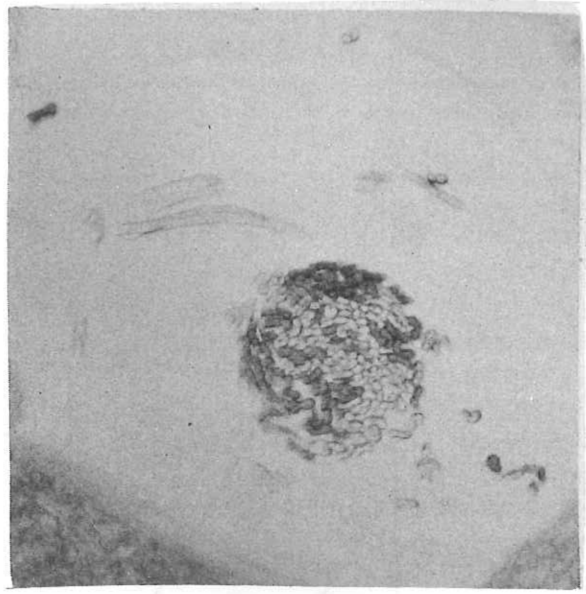


Figure 7B

Low-Twist 4/4 RDHD Pr D1

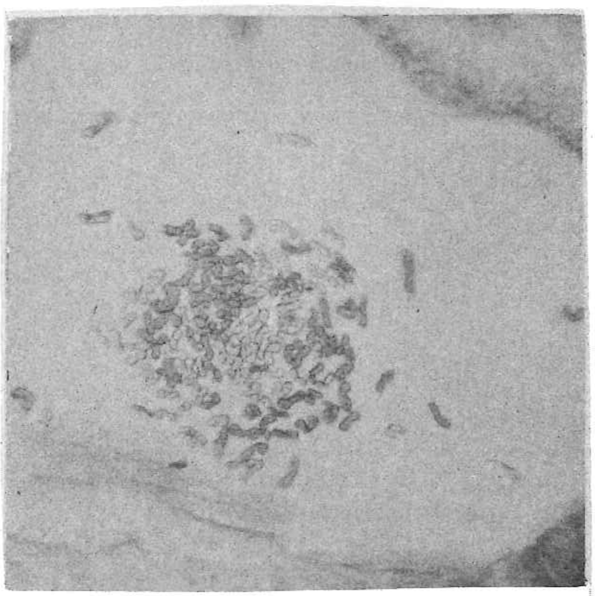


Figure 7C

Low-Twist 4/4 RDHD Core D1

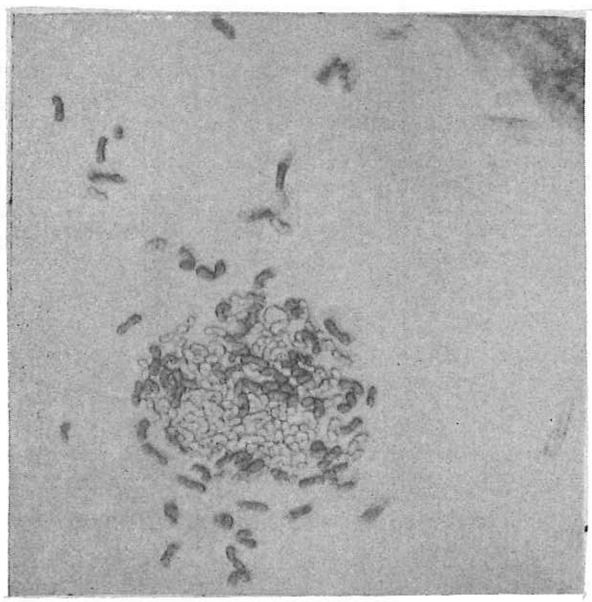
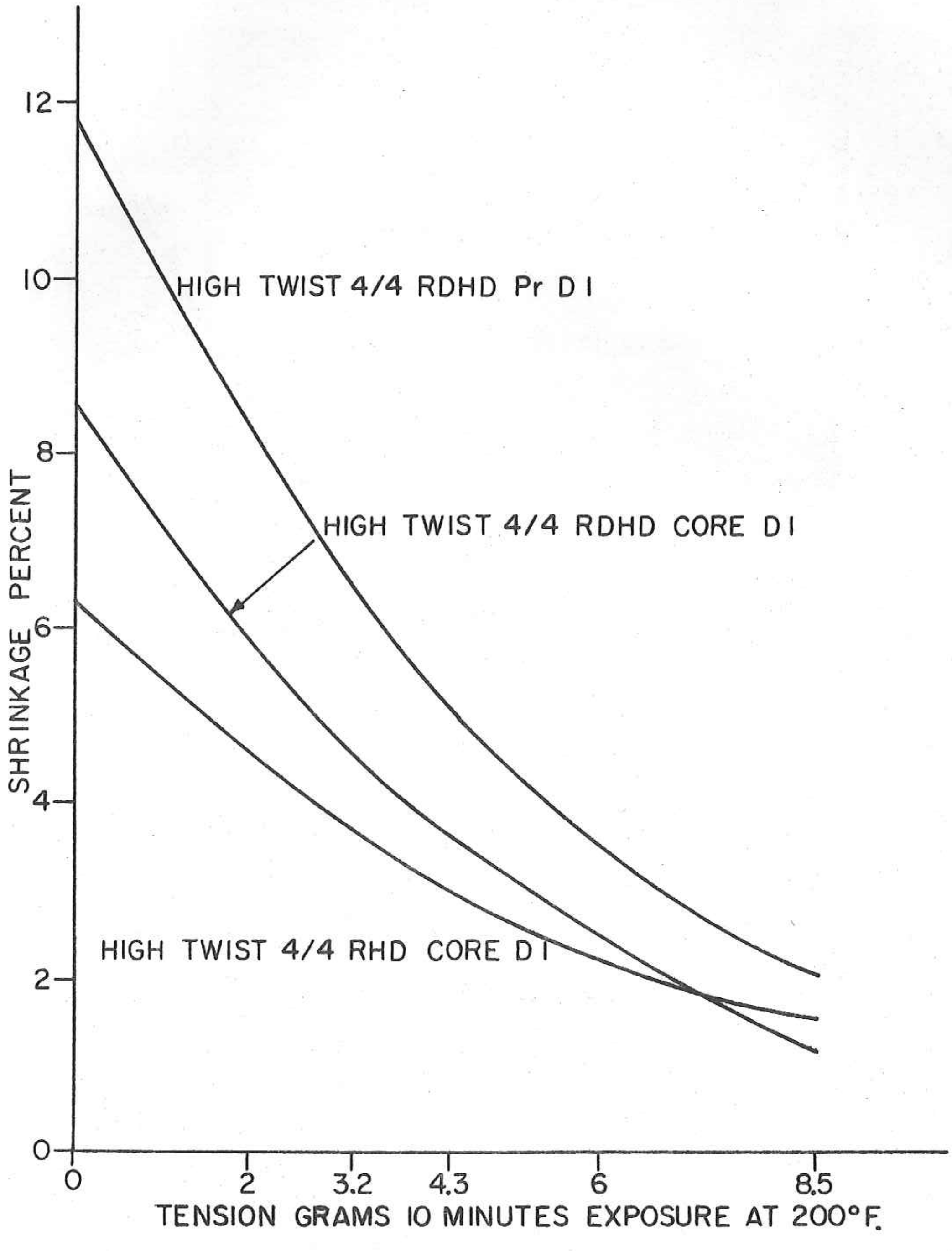


Figure 7D

Low-Twist 4/4 RHD Core D1



SHRINKAGE IN WATER OF 4/4 RDHD AND
4/4 RHD HIGH TWIST YARNS 16/1 cc

FIGURE 8

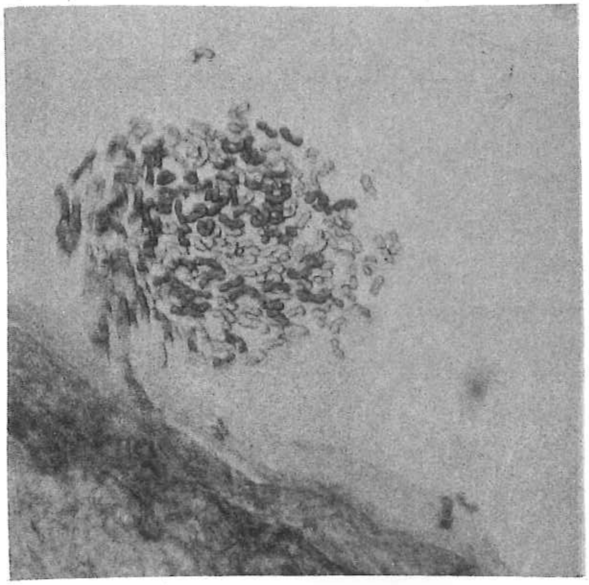


Figure 8A

High-Twist 4/4 RDHD Pr D1

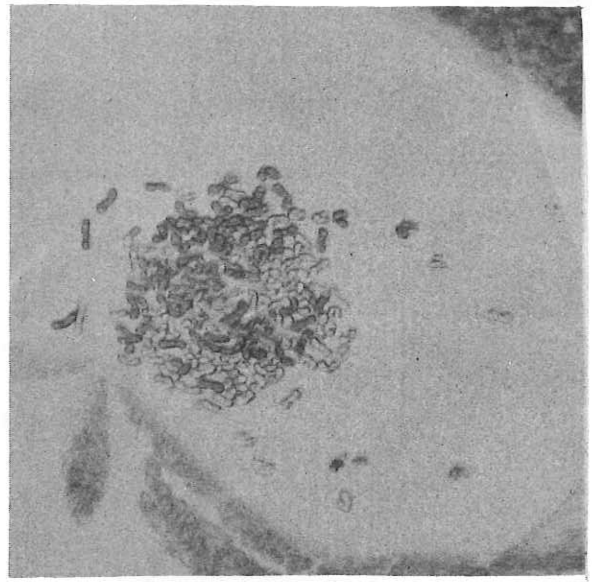


Figure 8B

High-Twist 4/4 RDHD Core D1

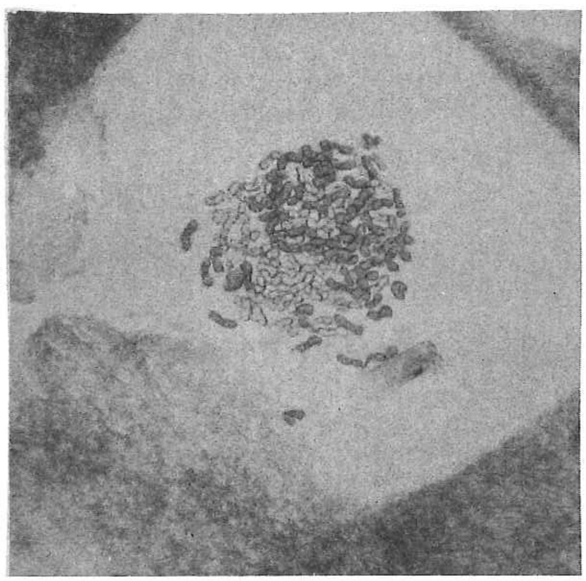
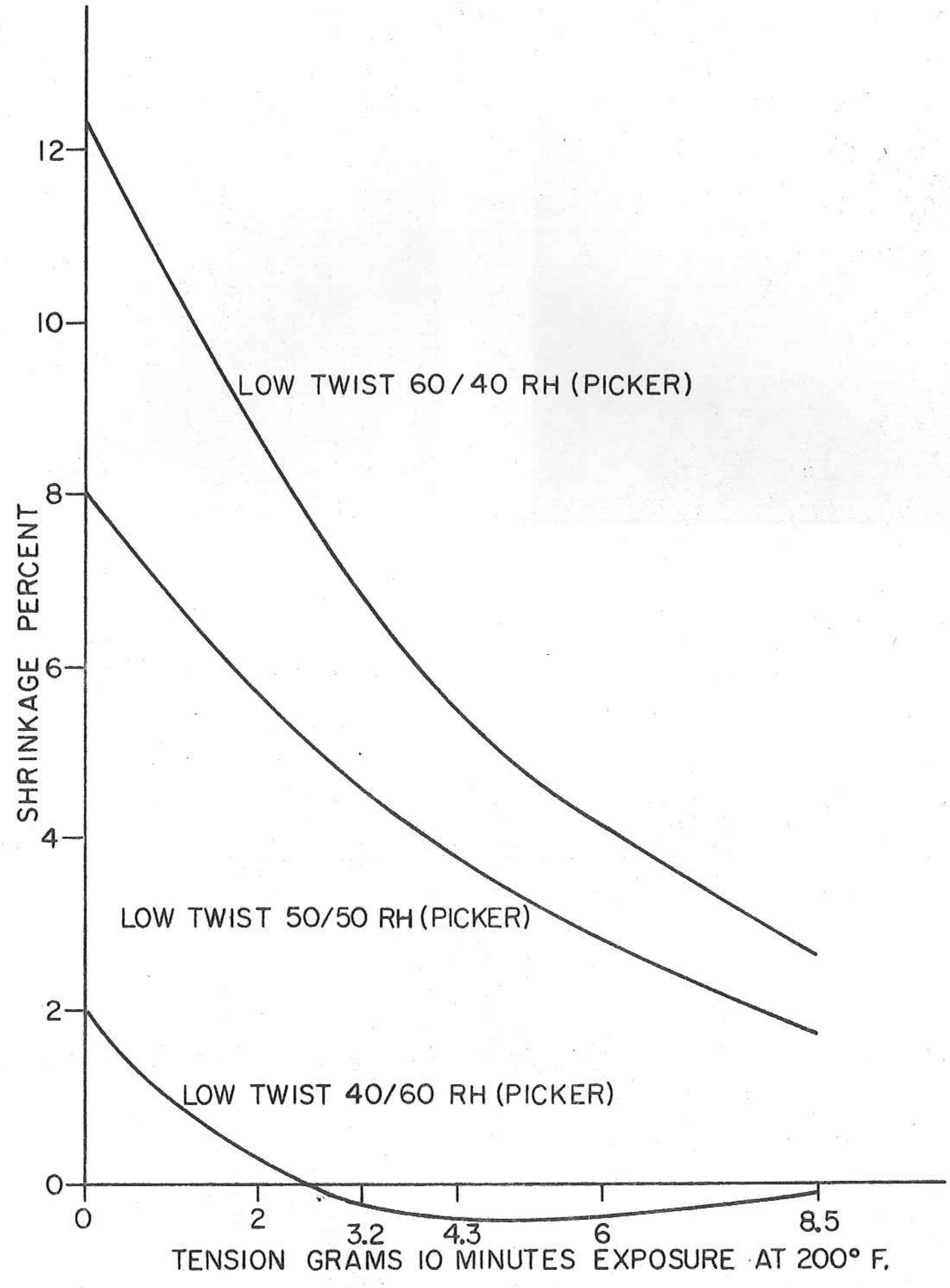


Figure 8C

High-Twist 4/4 RHD Core D1



SHRINKAGE IN WATER OF 60/40 RH, 50/50 RH AND 40/60 RH PICKER BLENDED LOW TWIST YARNS 16/1 cc

FIGURE 9

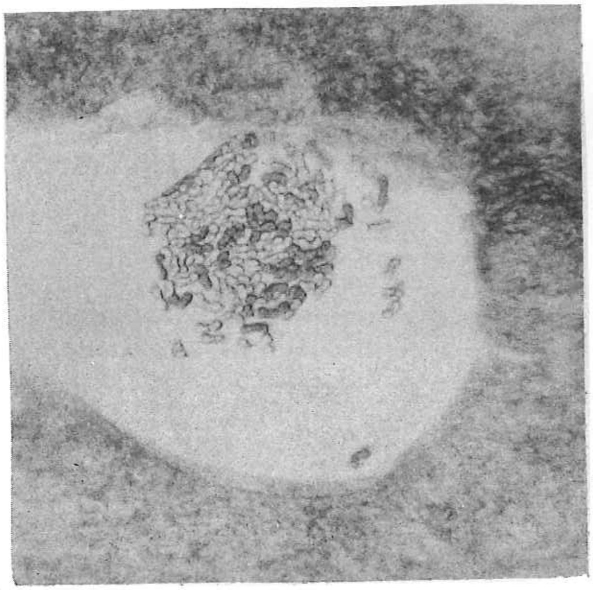


Figure 9A

Low-Twist 60/40 RH Picker Blend

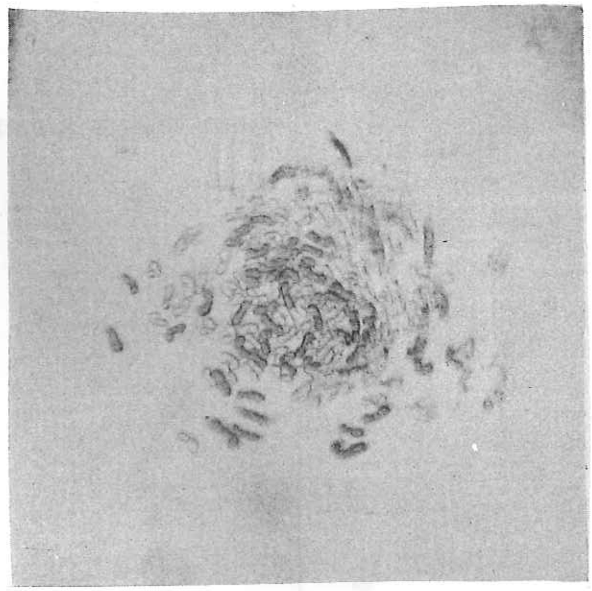


Figure 9B

Low-Twist 50/50 RH Picker Blend

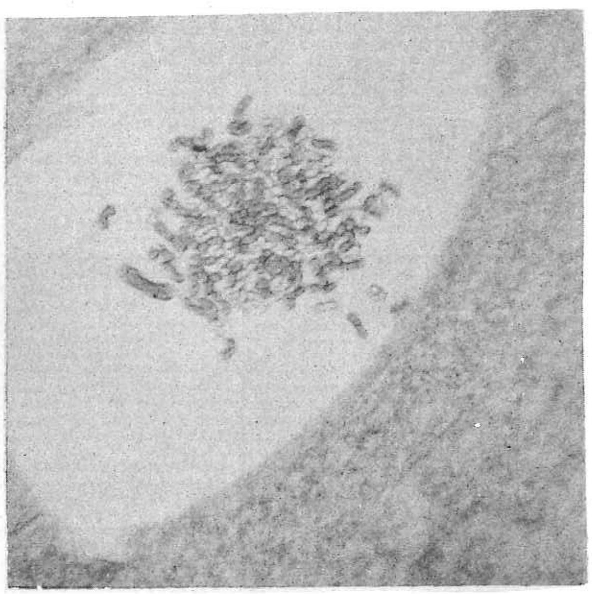
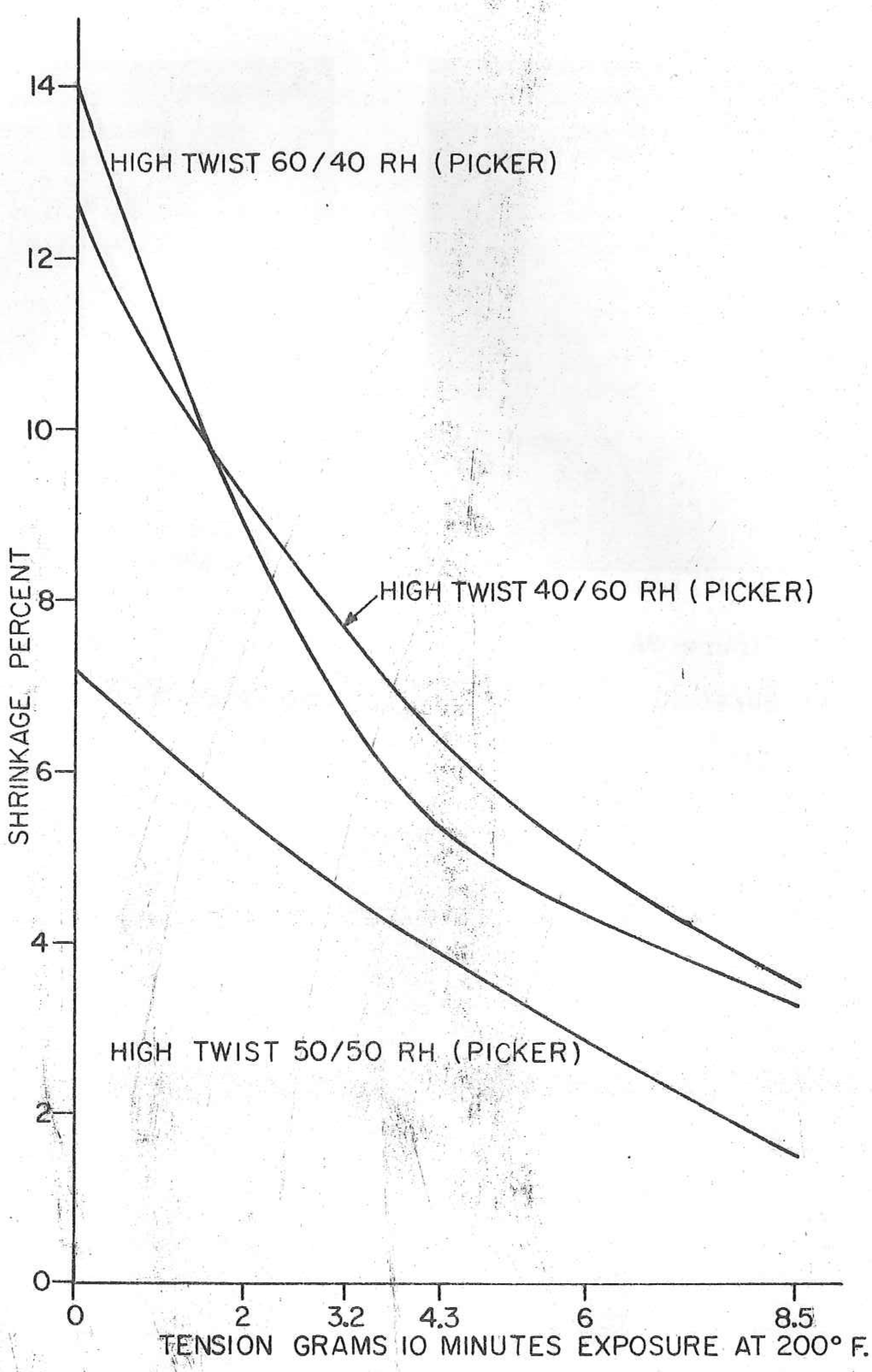


Figure 9C

Low-Twist 40/60 RH Picker Blend



SHRINKAGE IN WATER OF 60/40 RH, 50/50 RH AND 40/60 RH PICKER BLENDED HIGH TWIST YARNS 16/1 cc

FIGURE 10

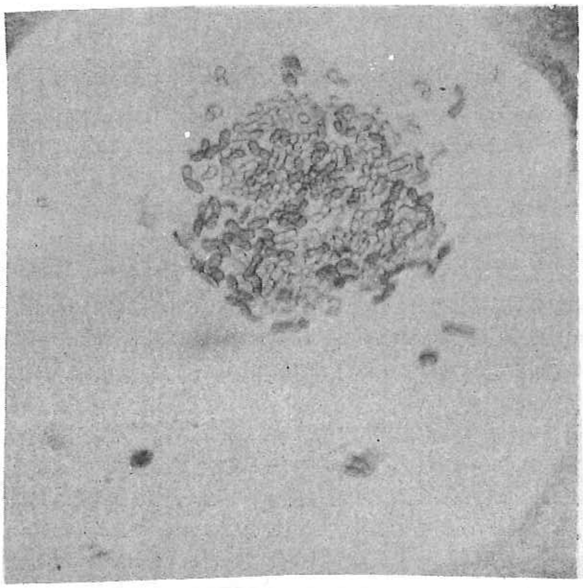


Figure 10A

High-Twist 60/40 RH Picker Blend

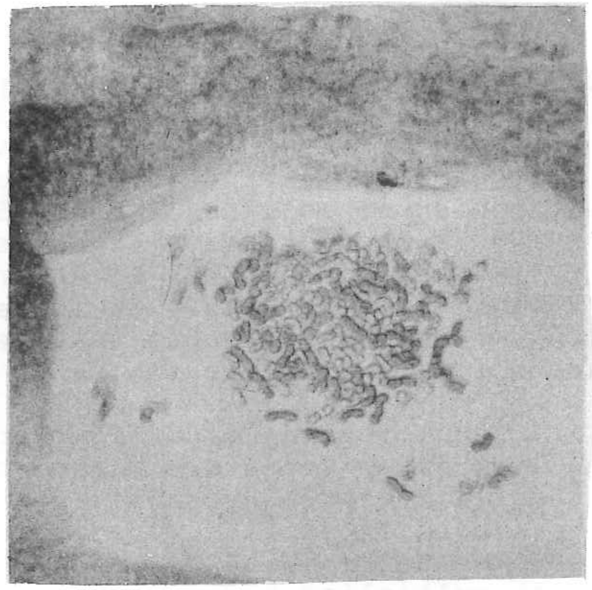


Figure 10B

High-Twist 40/60 RH Picker Blend

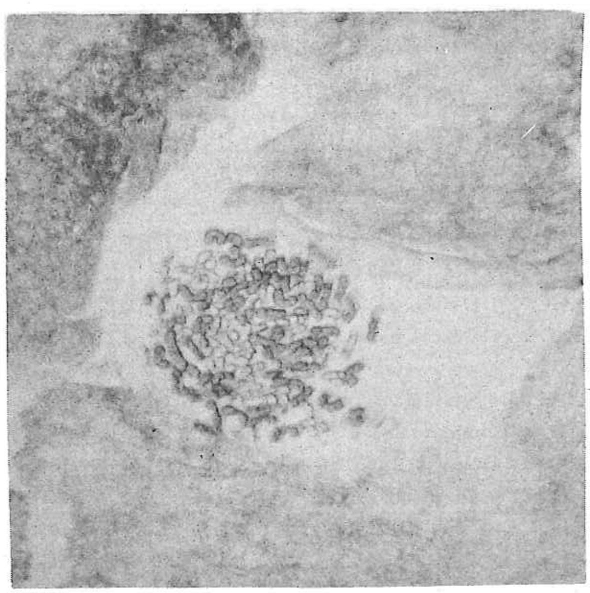


Figure 10C

High-Twist 50/50 RH Picker Blend

11. Conclusions

When Dynel fibers of "R" Type 180, 2 denier, and "H" Type 183, 3 denier, are blended in equal proportions, maximum yarn shrinkages measured over intervals of one-inch lengths occur when blending is performed by arranging card slivers "R" and "H" alternately at the first draw-frame process and simultaneously when the yarn twist multiplier is relatively low. Specifically, a twist multiplier of 2.8 is shown to give higher shrinkage than a twist multiplier of 3.4. Also, in terms of shrinkage, slivers arranged either "R" and "H" alternately or in pairs are superior to a core arrangement. There is evidence that two blending draw-frame passages are slightly superior to one in terms of enhanced yarn shrinkage.

The foregoing conditions appear to produce yarns in which the two fiber types are reasonably dispersed relative to each other in the yarn cross section, but in the longitudinal direction the fibers of similar types assume a reasonably continuous and unbroken path. With the fibers arranged in this fashion, the twist multiplier 2.8 apparently provides sufficient inter-fiber friction to permit the "H"-type fibers to contract and, simultaneously, take the "R"-type fibers along with them.

In the case of more homogeneous blends, such as would normally be produced by picker-blending followed by roller and clearer carding, the discontinuity of the fibers of a given type in the longitudinal direction of the yarn appears to produce a condition such that the shrinking "power" of the "H"-type fibers is unable to exert sufficient influence on the "R"-type fibers to produce a substantial overall yarn contraction. If, however, the twist multiplier is increased from 2.8 to 3.4, the additional fiber binding then creates a condition in which shrinkage is increased but at lower levels than with a draw-frame blended yarn of the same constituents.

For purposes of enhanced yarn shrinkage, there appears to be no advantage in increasing the percentage of "H"-type fiber from 50 percent to 60/62-1/2 percent. Indeed, there would seem to be a serious disadvantage, particularly when low twist is involved.

In terms of fabric behavior with a 50/50 RH picker blend warp, the highest cloth shrinkage after scouring occurs generally when low-twist filling is used. This is in agreement with yarn behavior. However, after the scoured fabric has been given a water-repellency treatment, a reversal occurs and highest cloth shrinkages are recorded with high-twist filling yarns. Presumably the curing temperature of 250°F is sufficient to induce contraction of the "H"-type fibers, which results in greater total yarn contraction in the high-twist yarn than in the low-twist yarn. This is not unreasonable in view of the more intimate fiber contact. In this context it will be noted that the temperature of the water

used for yarn shrinkage tests was 200°F and the drying temperature after scouring was also 200°F. Under these conditions, cloth shrinkage behavior was approximately the same as yarn shrinkage behavior except that the picker blends gave higher cloth shrinkage with low twist vis-a-vis high twist, whereas the yarn shrinkage trend was in the opposite direction. This is an interesting phenomenon and justifies further investigation.

Considering fabric shrinkage as a whole, there are only small differences in performance when the various blends and twists are compared. However, there are indications that a change in twist affects the relative shrinkage ability of some blends. For example, the 60/40 RH (picker) blend, when water-repellency treated, has the lowest ranking filling direction shrinkage with low twist, but becomes one of the highest ranking with high twist.

Air permeability tests on the water-repellency-treated fabric indicate that, in general, high-twist filling yarns produce a less permeable construction than low-twist yarns with the picker blends being particularly favorable. As with fabric shrinkage, there are relatively small differences in air permeability. Nevertheless, the 50/50 RH (picker) blend, high-twist water-repellency treated, is particularly good in respect to low air permeability, but is one of the least water-resistant specimens.

Water-repellency tests were very disappointing in that all samples failed the test. However, examination of the results reveals that the fabrics with low-twist fillings took somewhat longer to fail than did those with high-twist fillings. There is poor correlation of yarn and fabric shrinkage with air permeability and water resistivity, but the behavior of the blends 4/4 RH Pr Dl and 4/4 RDHD Pr Dl is worthy of note. Each shows favorable water resistance and, particularly after scouring, favorable air resistance.

12. Recommendations

a. Further experimentation could profitably be carried out in respect to fabric finishing; for example, scouring, the use of various other water-repellent materials, processing temperatures, and curing times.

b. An analysis of the mechanics of water penetration would assist in developing preventative measures.

c. It would be desirable to prepare further samples with slivers arranged in pairs employing both one and two draw-frame passages. The resultant yarn should be woven as warp and filling and compared with a standard 50/50 picker blend warp and filling.

APPENDIX

"CUP-TEST" PROCEDURE FOR WATER-REPELLENCY EVALUATION

A 10-inch by 10-inch fabric sample (face up) is placed over the top of a 1000 ml beaker (approximately 4.5 inches in diameter). The fabric shall be arranged so that the sample is depressed into the beaker by approximately 1.5 inches. A 200 ml distilled water at a temperature of approximately 25°C shall be gently poured into the depression. The underside of the fabric shall be noted for penetration of water. The fabric is considered to have failed this test when more than three drops of water penetrate to the underside in less than 24 hours.

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13. ABSTRACT

Regular and high shrink Dynel were blended in varying proportions and patterns and spun into 16^s yarns with two twists. Microscopic examination showed semblances of expected groupings, but the high shrink fibers tended to migrate to the outside. Shrinkages of the yarns in water (200°F) were measured under varying tensions. Minor loading reduced shrinkages to low levels, suggesting that mechanics of shrinkage in free yarn are different than those in fabric. There was little correlation of the yarn shrinkage results with the different combinations. Maximum shrinkage occurred in the 50/50, low-twist, draw-frame yarn with alternate feed. The least shrinkage in blended yarns was in low-twist yarns with greater proportions of high-shrink fiber. A 50/50 picker blend warp was woven with fillings from the various blends and twists. The fabrics were scoured and treated for water repellency. Highest shrinkage in scouring occurred with low-twist fillings while final shrinkage showed the reverse. High-twist filling yarns produced less air permeability. Differences in shrinkage and air permeability among various blend arrangements were not significant. There was little correlation among the results of yarn and fabric shrinkage and air permeability. All water repellency tests were poor; fabrics with low-twist fillings were better than those of high twist. Overall, among blended yarns, the 50/50 pair arrangements with one drawing seemed more favorable and distinctly better than the 50/50 picker blend. (All samples, including some woven with 100 percent regular shrink warp, have been retained by the U.S. Army Natick Laboratories for further analysis.

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Physical properties			7			
Air circulation			7			
Permeability			7			
Shrinkage			7		8,9	
Fabrics			7		9	
Comparison					8	
Picker blended					0	
Draw-frame blended					0	